The Cape Verde Atmospheric Observatory (CVAO) Observatório Atmosferico De Cabo Verde: Humberto Duarte Fonseca

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The Cape Verde Atmospheric Observatory (16.848°N, 24.871°W), a subtropical marine boundary layer atmospheric monitoring station situated at Calhau on the island of São Vicente, has been in operation since October 2006. Almost continuous measurements of the trace gases O_3, CO, NMVOC, NO, NO_2, NOy, (including more recently PANs, alkyl nitrates, nitrate aerosol, and HNO_3) have been obtained. Halocarbons (University of Bristol, UK) have been added to the suite in addition to various physical and chemical measurements of aerosol (Leibniz-Institut für Troposphärenforschung, Leipzig, Germany), and greenhouse gases such as CO_2, CH_4, N_2O, and SF_6 (Max Planck Institute fur Biogeochemistry, Jena, Germany). Over the last three years the observatory has supported additional short-term measurements of IO, BrO (University of Leeds, UK, University of Heidelberg, Germany), radiometry, and aerosol filtration, and has also been host to some campaign-style field measurements (RHaMBLe Reactive Halogens in the Marine Boundary Layer) project in Spring/Summer 2007: http://www.york.ac.uk/capeverde/RHaMBLe.html and SOS (Seasonal Oxidant Study) project in 2009: http://www.york.ac.uk/capeverde/SOS.html. The site is a contributing site to the GAW (Global Atmospheric Watch: http://gaw.empa.ch/gawsis/) network with data regularly uploaded to the WDCGG (World Data Centre for Greenhouse Gases: http://gaw.kishou.go.jp/wdcgg/) and in November 2006 it took part in an audit of the NMVOC measurements, executed by the Central Calibration Laboratory, IMK-IFU, Garmisch-Partenkirchen, Germany. Audits for the other measurements will hopefully follow this year. Funding has been granted until 2011 through various initiatives such as NCAS (National Centre for Atmospheric Science as National Capability: http://www.ncas.ac.uk/), and TENATSO (http://tenatso.ifm-geomar.de/) but provided the site meets expectations with regard to data quality and relevance, further funding will be sought to establish it as a continuing long-term observatory. If you are interested in “doing science” at the CVAO please contact Katie Read at km519@york.ac.uk. The site web pages can be found at www.york.ac.uk/capeverde.

Figure 1. The CVAO complete with newly erected wind turbine.

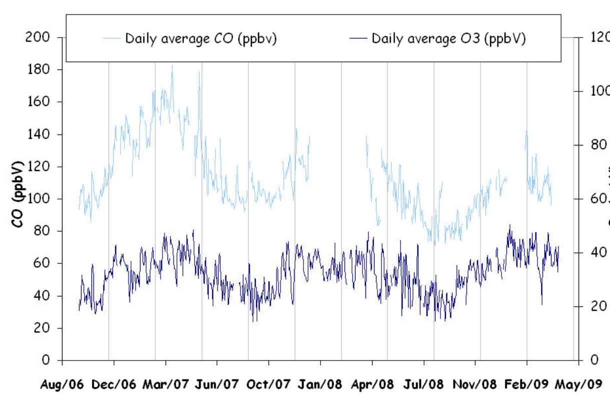

Figure 2. Daily average O_3 and CO measurements from the CVAO.

Long-Term Decline in Global Ethane Levels, 1984-2008

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Ethane is the most abundant non-methane hydrocarbon in the remote atmosphere. In an estimated budget of 15 Tg C yr^{-1}, it is believed to have two anthropogenic sources (biomass burning, 5.6 Tg C yr^{-1}, and fossil fuel, 4.8 Tg C yr^{-1}) and two natural sources (vegetation, 4.0 Tg C yr^{-1}, and oceans, 0.8 Tg C yr^{-1}) [IPCC, 2001]. As part of our long-term global monitoring network, which is based on seasonal whole air sampling using 2-L stainless steel canisters, we have measured the global ethane mixing ratio almost every season since 1984. During the past two decades there has been a remarkable long-term decline in global ethane levels of roughly 180 pptv (23%), from 791 ± 19 pptv in 1986 to 611 ± 10 pptv in 2008 (±1σ) (Figure 1). This long-term decline, which was more pronounced prior to 2000, is superimposed with short-term fluctuations every 3½ to 4½ years that are reminiscent of the short-term fluctuations in methane's growth rate. Because methane and ethane share only two common anthropogenic sources (biomass burning and fossil fuel) these results place important qualitative and quantitative constraints on the causes of methane's changing growth rate. Indeed, our most recent preliminary analysis using December 2008 data suggests that, for the first time in 24-years of simultaneous measurements, ethane and methane may be deviating from one another. These and other results will be discussed in the poster.

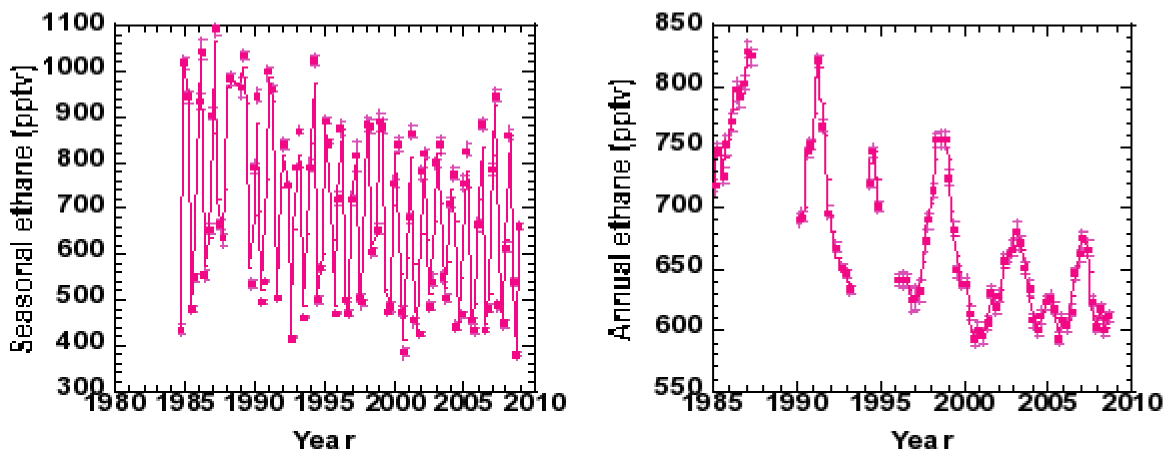

Figure 1. Global seasonal ethane mixing ratios (left) and global annual ethane mixing ratios (right) from Sep 1984 to Dec 2008. Each annual mixing ratio is plotted at the temporal mid-point of the year from which the average was calculated (e.g. Aug 1, 2008 for [Mar 2008 to Dec 2008]). The data are fit by an interpolated curve, i.e. a curve that passes through the data points and matches the slope at those points.

Validation of *In Situ* Measurements for Analysis of CO_2, CH_4 and H_2O in Aircraft

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As the NOAA ESRL Carbon Cycle Group Aircraft Project grows there has been a significant effort to develop the capability to make *in situ* measurements of CO_2, CH_4 and CO for short-term campaigns as well as long-term monitoring. In particular, we are currently focused on participating with In-Service Aircraft for the Global Observing System (IAGOS) which will utilize both Airbus A340 and A330 aircraft for regular sampling throughout Europe, Asia and North America on commercial aircraft. The goal of this development project has been to create an instrument which is stable under conditions where ambient temperature, humidity and pressure are likely to change rapidly. Because access to the instrument will be limited, the need for consumables will have to be limited. The instrument must therefore be able to accurately measure air that has not been chemically or cryogenically dried and with minimized reliance on standards. The result of putting 10 instruments on commercial aircraft could provide up to 21,000 profiles per year which would be an enormous increase over the current 450 profiles collected at 16 sites around North America each year.

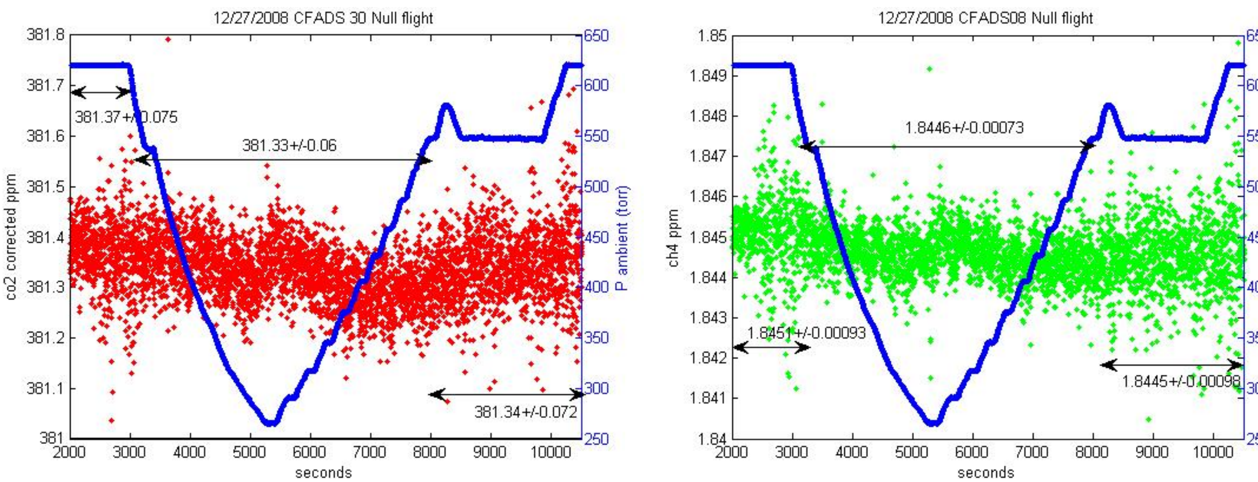

Figure 1. Null test for flight in Cessna 210 over Briggsdale, CO on December 27, 2008 for CO_2 and CH_4. By sampling a single standard for the duration of the 2.5 hour flight it can be shown that the instrument pressure (blue line) and ambient temperature (not shown but varied by 10°C) resulted in only small changes in the instrument noise or bias throughout the duration of the flight.

Vertical Profiles of CO, CH_4 and CO_2 Above Poker Flats, Alaska, Molokai, Hawaii and Rarotonga, Cook Islands

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Between 1999 and 2007 vertical profiles of carbon monoxide (CO) were measured as part of the validation plan for the MOPITT instrument (positioned on the TERRA satellite). Air samples were collected bimonthly with 300-500 m resolution between 0.5 and 8 km above Poker Flats, Alaska (PFA; 65.1°N 147.5°W), Molokai, Hawaii (HAA; 21.4°N 157.2°W) and 0.5 and 6km above Rarotonga Cook Islands (RTA; 21.2°S 159.6°W). CO_2 and CH_4 were also measured in the air samples. The seven-year timeseries provide a rare picture of the vertical distributions, seasonal cycles and interannual changes of these gases. Here we will compare results from Alaska, Hawaii and Rarotonga. A key feature of the over 750 measured profiles is their high degree of temporal and spatial variability. Within a profile, discreet enhancements in one species are often mirrored in the other carbon gases suggesting a common source or transport from source areas. Above Poker Flats and Molokai, the seasonal cycles of the three gases are well defined. The timing of the seasonal maximum and minimum at altitude lagged up to a month behind the surface and amplitudes of the cycles decreased with altitude. In the low Southern Hemisphere, the seasonal amplitude was greater at altitude and more similar in timing throughout the column. Seasonal cycles of CO_2 simulated with the TM5 (a chemical transport model) compare well with the measurements.

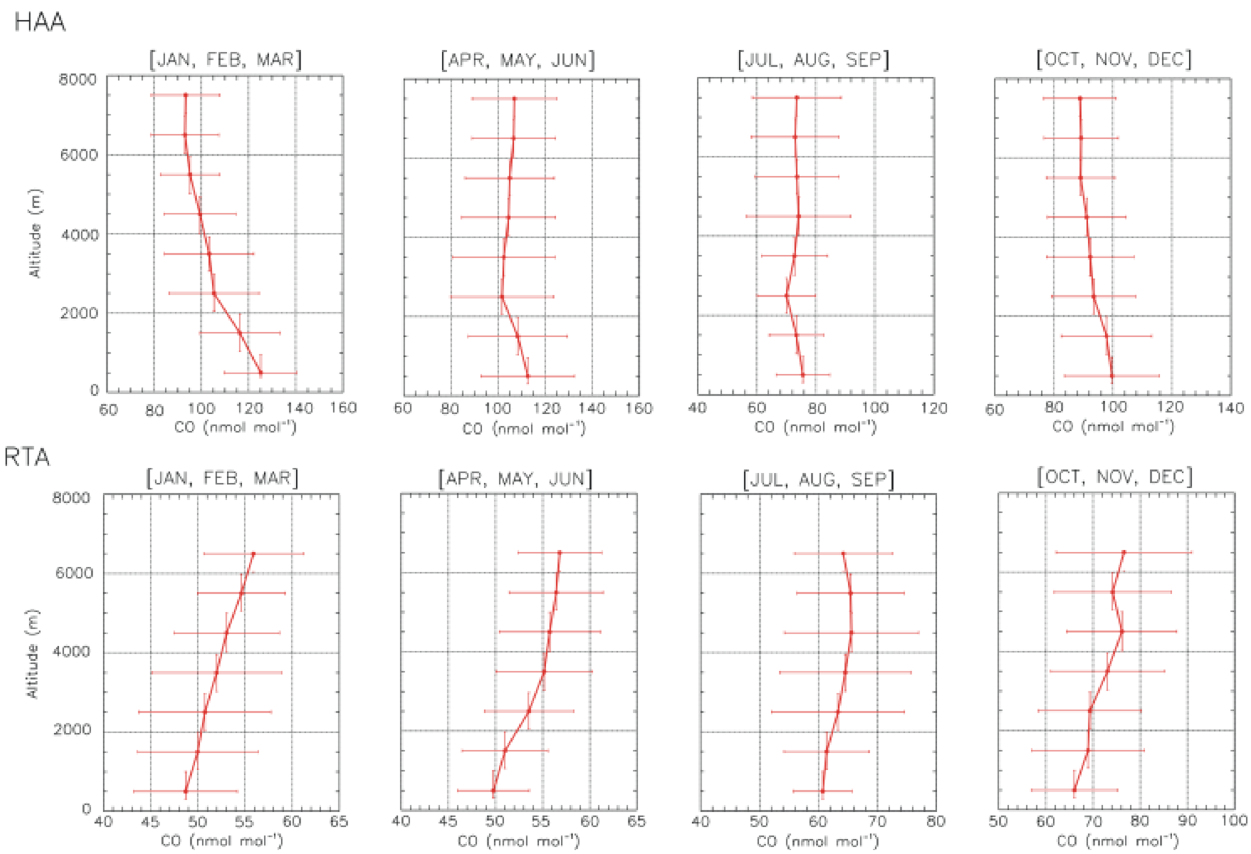

Figure 1. Seasonally averaged vertical profiles of CO above HAA and RTA. Mixing ratios above HAA show a decrease with altitude in winter, likely due to vertical mixing of polluted surface air. CO tends to increase above RTA suggesting transport from either the NH or South America and Africa.

Carbon Tracker - CH_4

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We present first results from an assimilation system designed to produce ongoing estimates of atmospheric methane sources and sinks using ESRL network observations, the TM5 atmospheric transport model and an ensemble Kalman Smoother. The inversion covers the time period 2000 through 2007. Notable features of the flux estimates include interannual variability of emissions from wetlands, and a shift of maximum emissions towards later in the growing season for high Northern Boreal regions. We examine the partitioning of the methane budget between anthropogenic and natural sources, as well as the attribution of interannual variability.

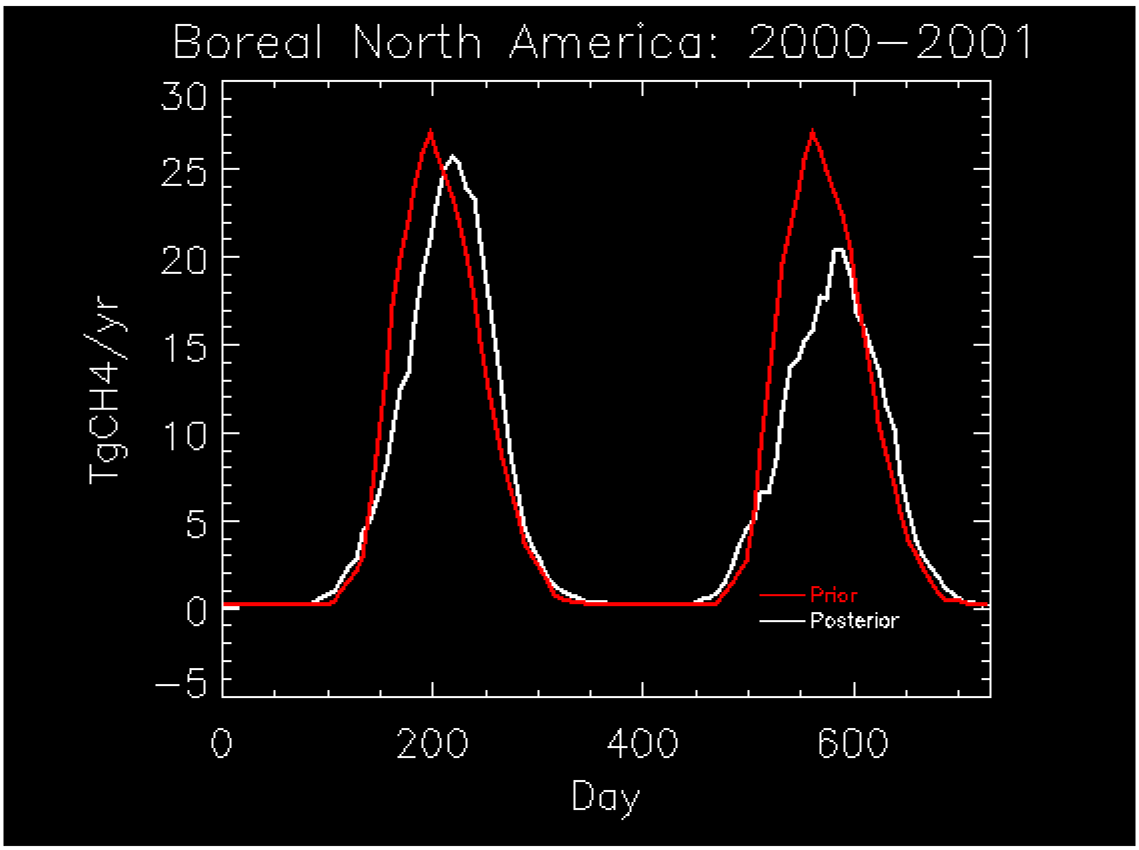

Figure 1. Estimated methane fluxes from Boreal North American wetlands for two years. The maximum emissions are shifted later in the growing season, and the fluxes vary considerably between the two years.

Quantifying CH_4 Emissions with Airborne Differential Absorption Lidar Data

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A new laser-based technique for airborne quantification of methane emission rates has been developed and in early tests has proven to be quick and efficient. Methane is the second most important anthropogenic greenhouse gas in the atmosphere. Sources of methane include emissions from landfills, natural gas production, transportation and distribution, coal mining, coal bed methane development, and agriculture. Methane emissions which are diffuse or poorly located have traditionally been difficult or impossible to quantify with existing techniques. The CH_4 plume quantification technique uses airborne differential absorption lidar (DIAL) data collected using ITT's Airborne Natural Gas Emission Lidar (ANGEL) Service combined with wind data. During a series of flight tests in April 2008, the quantification technique proved to be accurate within 28% in calculating the emission rate of known calibration leaks. Over the past 18 months, working with 3 separate commercial pipeline owners in the United States and Canada, researchers have quantified a total of 66 simulated pipeline leaks. Airborne estimates matched the calibrated release rates within a factor of two >73% of the time. The major source of error in measuring emission using airborne DIAL data is in the accuracy of the associated wind data. In March 2009, for the first time airborne DIAL data was used to estimate methane emissions from a landfill in upstate New York (Fig. 1). A single landfill was measured to be emitting between 800 and 2,100 tons of methane per year. Work is underway to extend this work to include airborne CO_2 DIAL measurements.

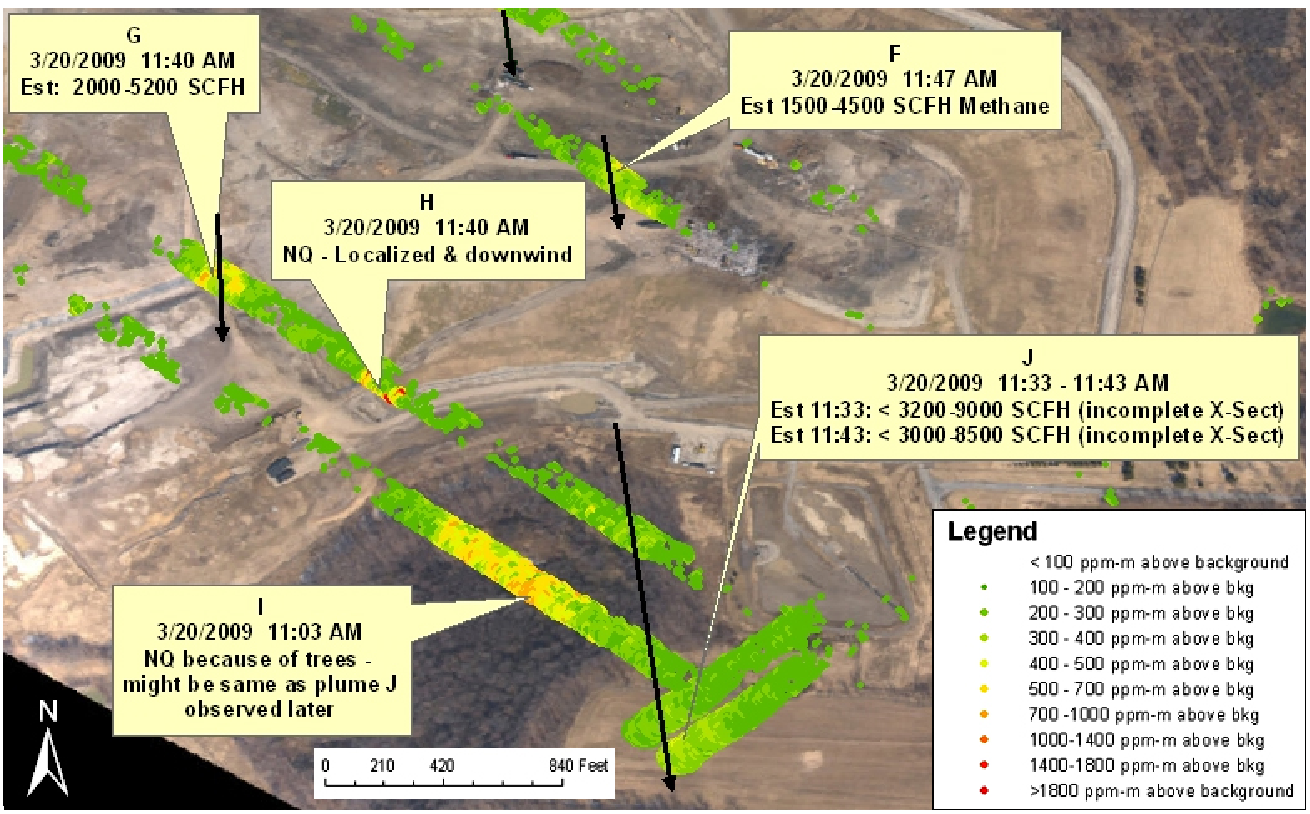

Figure 1. Quantification of multiple CH_4 plumes from an operating landfill using airborne DIAL data. Measurements were collected in 6 separate passes and CH_4 concentrations above background are represented in shades of green, yellow and red. Wind data for this collection was obtained from the closest NWS weather station.

Column CO_2 Estimates at ARM-SGP

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We report on column CO_2 estimates from the ARM Climate Research Facility in the Southern Great Plains (36.6053° N, 97.4891° W, near Lamont, Oklahoma). Data include multi-year variations in midday near-surface (60 m) CO_2 mixing ratios, a multi-year record of periodic CO_2 profiles (to ~ 5 km) from a small aircraft, and initial column CO_2 retrievals made with a Fourier transform spectrometers (FTS) deployed at the SGP site. Using *in situ* CO_2 mixing ratio measurements, we estimate column CO_2 over time and compare with the FTS retrievals. We also evaluate the temporal variations in estimated column CO_2 at SGP as well as the relative contributions to variation with altitude along the vertical profile. These results provide an initial evaluation of the FTS retrievals at ARM-SGP in preparation for comparisons with future validation of GOSAT.

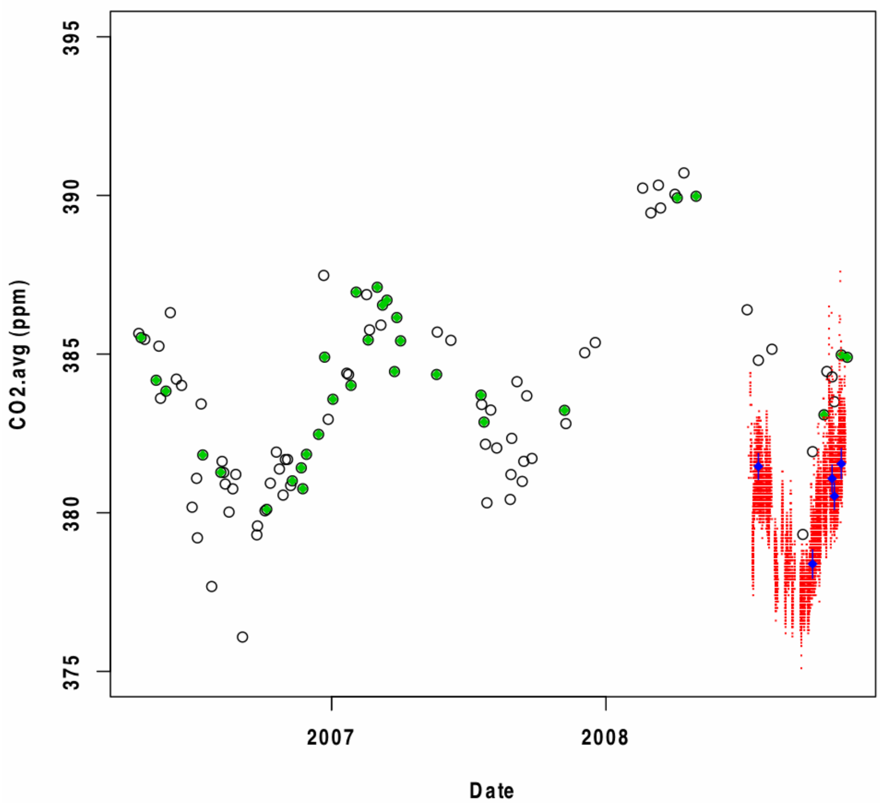

Figure 1. Column average CO_2 mixing ratio from the combination tower and airborne flask measurements (0.3 to ~ 5 km) for morning (open circles) and afternoon (green circles) samples, full column estimates from a Fourier transform spectrometer for all retrievals (red) and averaged into 1 hr bins surrounding airborne measurements (blue).

Comparison of LM3V and Carbon Tracker Data: Initial Results

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We use the Dynamic Vegetation Model LM3V - jointly developed at NOAA GFDL and Princeton University - to simulate ecosystem dynamics and exchanges of water, energy and CO_2 between land and atmosphere, and compare these results with the NOAA ESRL Carbon Tracker model. LM3V includes 5 vegetation carbon pools (leaf, sapwood, heart wood, fine root, virtual leaf) and 2 soil carbon pools (fast and slow soil carbon). The model uses a simple characterization of biodiversity, which includes 5 vegetation type (C3 cold grass, C4 warm grass, temperate deciduous forest, tropical broad leaf forest and evergreen coniferous forest). The model is forced by the High-Resolution Global Dataset, which was specifically developed for land surface modeling. The size of the model grid cell is flexible, and each cell can be further divided into 4 tiles, which track the dynamics of the primary, cropland, pasture and secondary vegetation for land-use transitions. We perform a series of experiments with LM3V to investigate the model sensitivity to parameter settings and to external forcing. Model results are compared with the Carbon Tracker output, which can be used to fine tune the model with the parameters that are most sensitive. Initial results suggest that NPP and GPP are sensitive to many of the parameters related to tropical vegetation type.

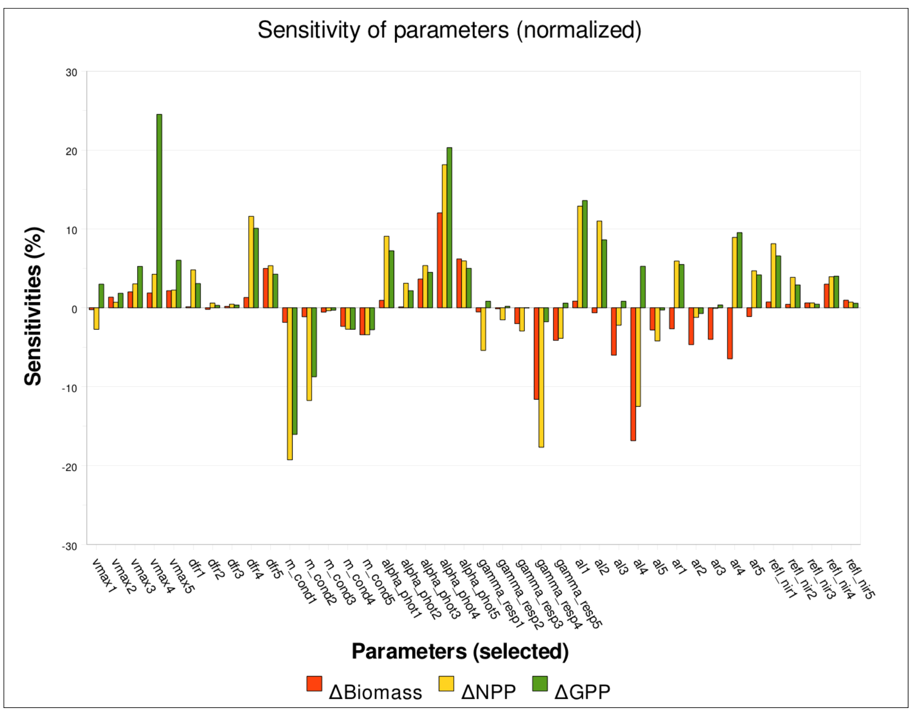

Figure 1. Sensitivity of parameters due to perturbations from the mean state of a control run. Because most of the parameters are non-linear, sensitivities of each parameter may differ from a different mean state. The maximum velocity of carboxylase (Vmax) of C4 warm grass affects NPP and GPP in the opposite direction and is a good parameter for tuning the GPP/NPP ratio. The bulk water conductance parameter (dfr) is not always as sensitive as previously believed. The “dfr” for C3 cold grass (dfr2) and C3 temperate deciduous forests (df3) are not sensitive from this mean state.

Identification of Greenhouse Gas Source Signatures in the San Francisco Bay Area Using *In Situ* Aircraft Measurements

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Quantification of specific sources and sinks of greenhouse gases is necessary for validation of emission flux estimates and supports recent efforts to regulate greenhouse gas emissions. *In situ* atmospheric measurements provide a valuable contribution to the effort of quantifying sources and sinks. In this study, continuous *in situ* measurements of carbon dioxide, methane, and carbon monoxide were made from a light aircraft in the San Francisco Bay area between June 17 and June 24, 2008 and again between February 24 and March 7, 2009. In addition to the continuous measurements, twelve flask samples were taken on each flight using NOAA ESRL Programmable Flask Packages. These samples provided measurements of a variety of additional atmospheric trace gases, including N_2O, H_2, benzene, HCFCs, and additional halocarbons. Atmospheric transport and footprints for the flight tracks in 2008 have been computed using the Stochastic Time-Inverted Lagrangian Transport (STILT) model driven by customized output from the Weather Research and Forecasting (WRF) model, allowing for an analysis of the origin of the various air masses observed. Large signals were observed during the campaign: urban air plumes with highly correlated CO_2, CH_4 and CO, as well as agricultural signatures with enhanced CH_4 coincident with depleted CO_2. The flights of June 2008 captured a large signal from the northern California wildfires as well, enabling the comparison of the signatures from the fires to those of other sources. The flights in February and March of 2009 were targeted around known local sources of CO_2 and CH_4 affecting the continuous NOAA and LBL measurements on the tall tower at Walnut Grove, CA.

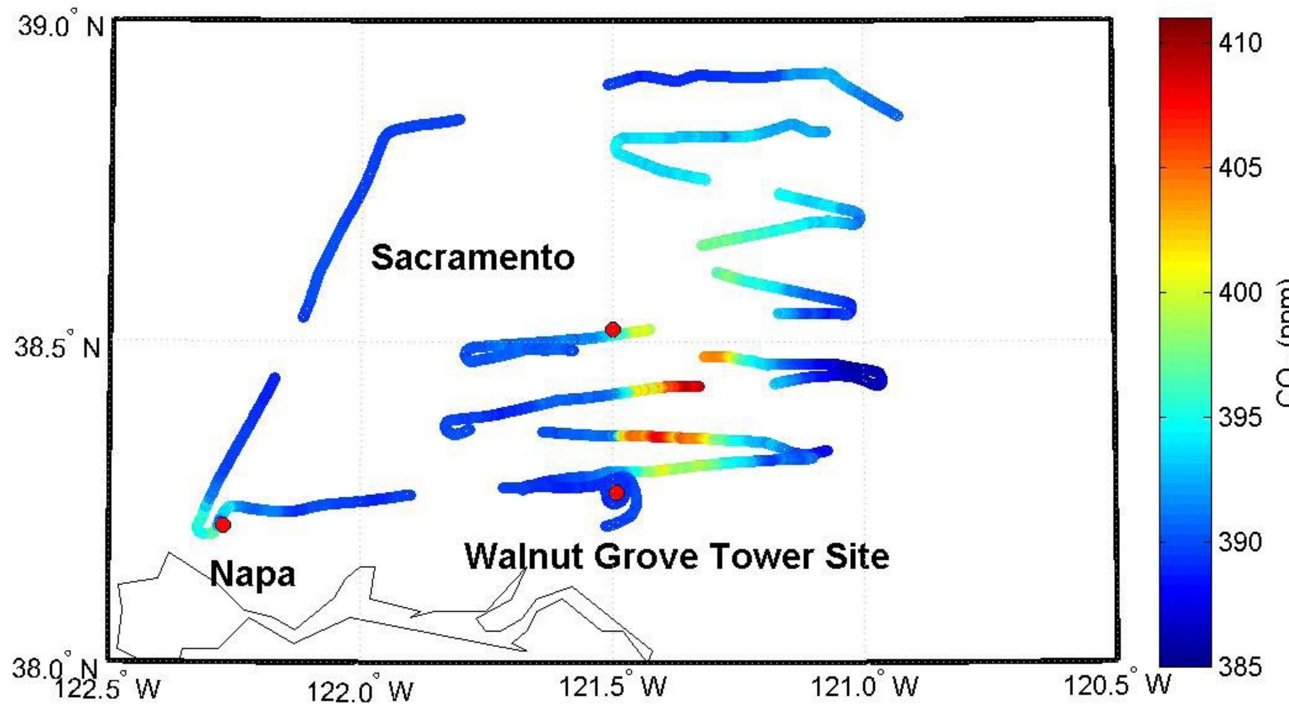

Figure 1. Continuous CO_2 measurements downwind of Sacramento made on February 27, 2009.

Reconciling Modeled Ocean Carbon Fluxes With Atmospheric ^{13}C Observations

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As atmospheric greenhouse gas concentrations rise, researchers seek to identify how Earth's climate and carbon cycle are affected. To close the atmospheric CO_2 budget, several major fluxes must be accounted for: fossil fuel, ocean, and land, and ^{13}C can be a useful tools in distinguishing them. One drawback to this method is that photosynthesis and respiration are not contemporaneous, and because the ^{13}C of atmospheric CO_2 is being continuously depleted through the burning of ^{12}C-rich fossil fuels, there is an isotopic "disequilibrium flux" between CO_2 moving into and out of the ocean and land reservoirs. In this study, we use a combination of atmospheric CO_2 and $^{13}CO_2$ data, fossil fuel emission estimates, and recent ocean model results for the ocean CO_2 flux, within a box-inverse model. We calculate time series of land flux, disequilibrium flux and photosynthetic fractionation from 1991 through 2006. Initial findings reveal that if ocean variability is as small as is suggested by the ocean model, and the isotopic variability is forced into the disequilibrium flux, then the resulting disequilibrium flux has very large interannual variability (~35 PgC‰/yr), and an increasing trend. An intriguing possibility is that both the ocean model predictions and the atmospheric measurements can be satisfied by driving the variability into the photosynthetic fractionation term, εab. Under this scenario, relatively small interannual variations in net carbon exchange of C3 and C4 vegetation would be sufficient to explain the otherwise seemingly incongruent nature of the ocean model results and atmospheric observations. Best estimates of land, ocean, and disequilibrium fluxes, as well as photosynthetic fractionation and C4 net terrestrial exchange will be presented.

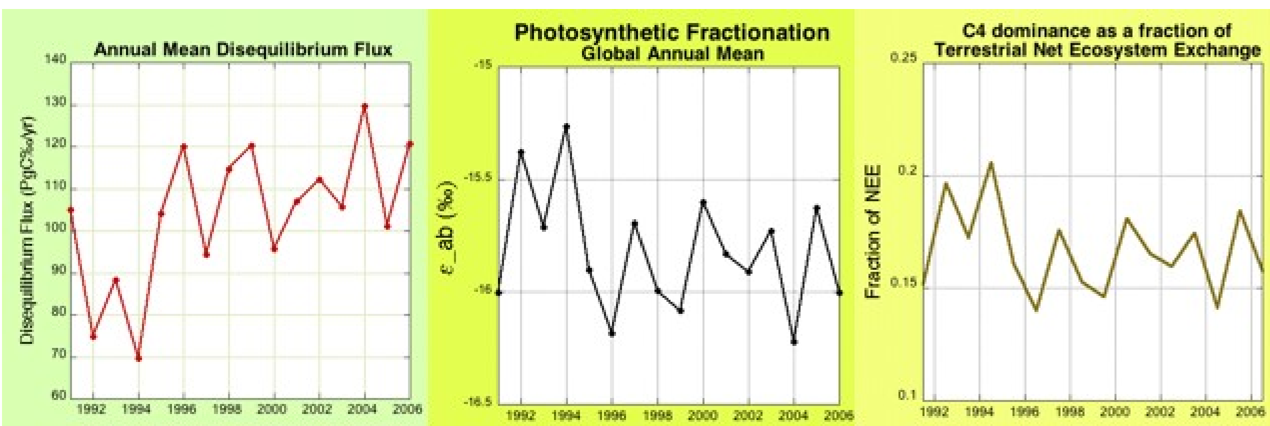

Figure 1. Disequilbrium flux is derived from ocean model results and atmospheric observations in a box-inverse model. The subsequent plots are end-member scenarios in which all disequilbrium flux variability is driven into εab and C4 dominance, respectively.

Quantification of Fossil Fuel CO_2 Emissions from East Asia Using Atmospheric Observations of $\Delta^{14}CO_2$

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Fossil fuel CO_2 emissions are the largest annual net source of CO_2 to the atmosphere, and accurate quantification of these emissions is essential to furthering our understanding of the global carbon cycle. Currently, these fossil fuel CO_2 (CO_2ff) emissions are estimated from economic inventories of fossil fuel use reported by governments and industry. Measurements of the radioactive isotope ^{14}C in CO_2 ($\Delta^{14}CO_2$) provide an independent method of constraining CO_2ff emissions, since fossil fuel derived CO_2, unlike other CO_2 sources, is devoid of ^{14}C. Emissions from East Asia in recent years are of particular interest, since they contribute ~25% of global total emissions, and are rapidly growing by 8-10% per year, but with an estimated uncertainty of ±20% on the annual total (compared to ±3-5% for European and North American emissions). We quantitatively determine recently added CO_2ff in samples from the NOAA ESRL cooperative sampling network at sites in East Asia, focusing on Tae-Ahn Peninsula, South Korea (TAP), which typically sees air which has recently passed over northern China and Korea. Samples typically contain a few ppm of CO_2ff from China, and in some samples, Korea contributes up to 20 ppm of CO_2ff; these values are much larger than the detection limits of the method. The observed CO_2 also shows large variability due to biospheric CO_2 exchange, even in winter, so that CO_2 measurements alone cannot accurately estimate CO_2ff. We compare the observational results with estimates of CO_2ff from a Lagrangian particle dispersion model (FLEXPART) and a prior estimate of CO_2ff emissions, examining our ability to model atmospheric transport for this region, and ultimately, to validate the reported emissions and determine quantitative uncertainties on the emissions.

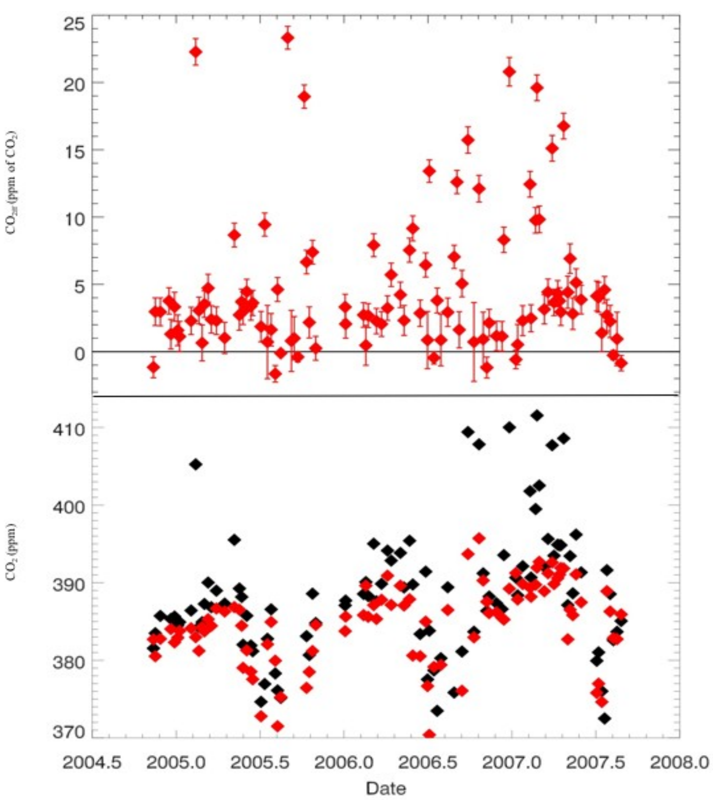

Figure 1. Top panel: Recently added fossil fuel CO_2 (CO_2ff) at TAP, calculated relative to a free tropospheric background. Error bars are the measurement uncertainty. Bottom panel: Total CO_2 mixing ratio measured in the same samples at TAP (black points). When the CO_2ff contribution in each sample is subtracted, the red points reveal a seasonal cycle driven by biospheric CO_2 exchange.

CARBONTRACKER: Sensitivity to Potential Systematic Bias in CO_2 Observations

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CarbonTracker is a combined observing and modeling system that estimates CO_2 uptake and release at the Earth's surface over time. CarbonTracker uses high-precision atmospheric CO_2 observations to optimize derived surface flux estimates based on our current understanding of CO_2 exchanges between the atmosphere, ocean and terrestrial biosphere. Sources of uncertainty in CarbonTracker flux estimates likely include biases in 1) the prescribed emission inventories; 2) the prior emission estimates derived from process models; 3) the atmospheric transport model; 4) the flux optimization scheme; and 5) the observational network. Unknown systematic biases are of critical concern as they may produce incorrect emission estimates. Several studies are underway to specifically assess biases and uncertainty as requested by last year's CarbonTracker Science Review team. Here we explore the sensitivity of CarbonTracker emission estimates to potential biases within observational records. We perform several simulations where we introduce systematic offsets for a fixed period of time at selected sites and compare emission estimates with those from the current CT2008 release (carbontracker.noaa.gov). Sensitivity depends both on the site's proximity to source regions and the existence of other measurement sites nearby. Here we present results from simulations using CO_2 observations from the LEF tall tower in Wisconsin. We find that a +1.0 ppm systematic offset introduced to the 2004 LEF data leads to a 0.13 Pg C (17%) reduction in terrestrial uptake in temperate North America and a corresponding increase in uptake in temperate Eurasia. We discuss these results and how they scale when more realistic biases may exist in observations.

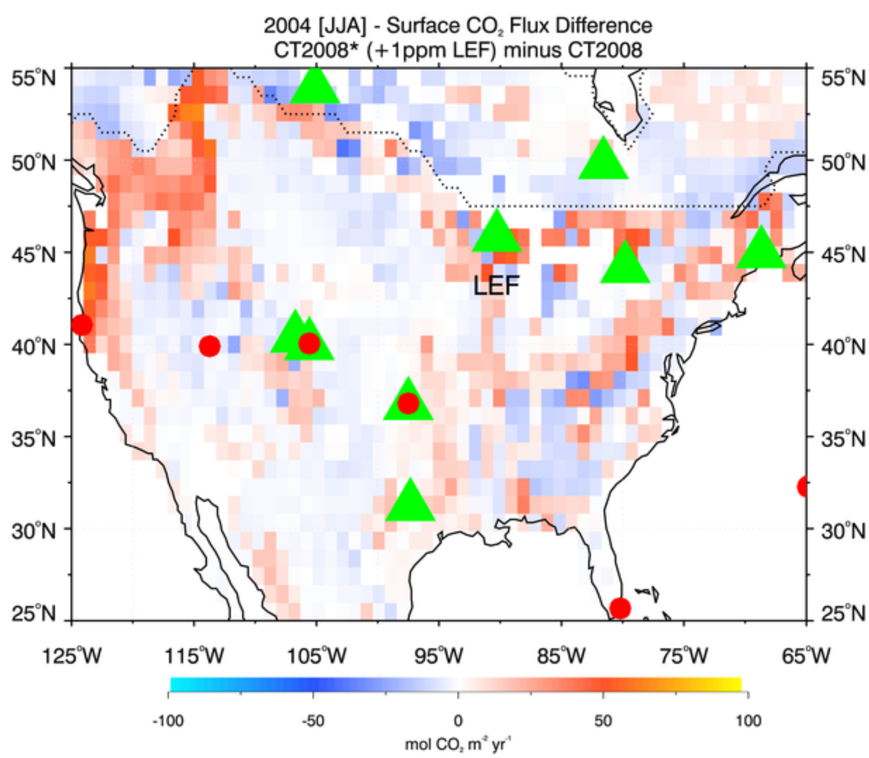

Figure 1. Shows summer 2004 surface CO_2 flux differences, CT2008* minus CT2008, where CT2008* is a CarbonTracker run that includes an introduced +1 ppm systematic offset to the 2004 LEF quasi-continuous CO_2 atmospheric measurements and CT2008 is the current CarbonTracker release. Warm colors indicate that CT2008* estimates less surface CO_2 uptake by the terrestrial biosphere than CT2008; cool colors indicate greater surface uptake; and white indicates no difference. Quasi-continuous tower sites (green triangles) and weekly surface measurement sites (red circles) included in the assimilation are shown.

Data Quality and Continuity for the ESRL GMD Tall Tower Network

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New *in situ* instrumentation for measuring CO_2 and CO was developed to facilitate the expansion of the ESRL GMD Tall Tower Network. The first of the new analysis systems was deployed in May 2006 to the WKT site near Moody, TX. Since then, nearly identical systems have been deployed to six other sites across the U.S. The systems are fully automated and extensive engineering data is recorded and tracked using elaborate quality control algorithms. Eight calibration standards are deployed with each instrument, five of which are dedicated to CO_2 and three for CO. The calibration suite includes a “target” gas for each molecule. The target tank is routinely measured but is not used to compute the calibration polynomial. The repeatability of the target measurements and the agreement between measured and assigned target values are key indicators of measurement precision and system performance. Six of the sites are also equipped with automated flask sampling systems, and comparison of data from the *in situ* and flask sampling systems is another measure of data quality. We will present an overview of the data quality across the network and also a summary of common failure modes and instrument downtime for each site. We will also evaluate the calibration stability in order to determine whether calibration gas usage can be reduced.

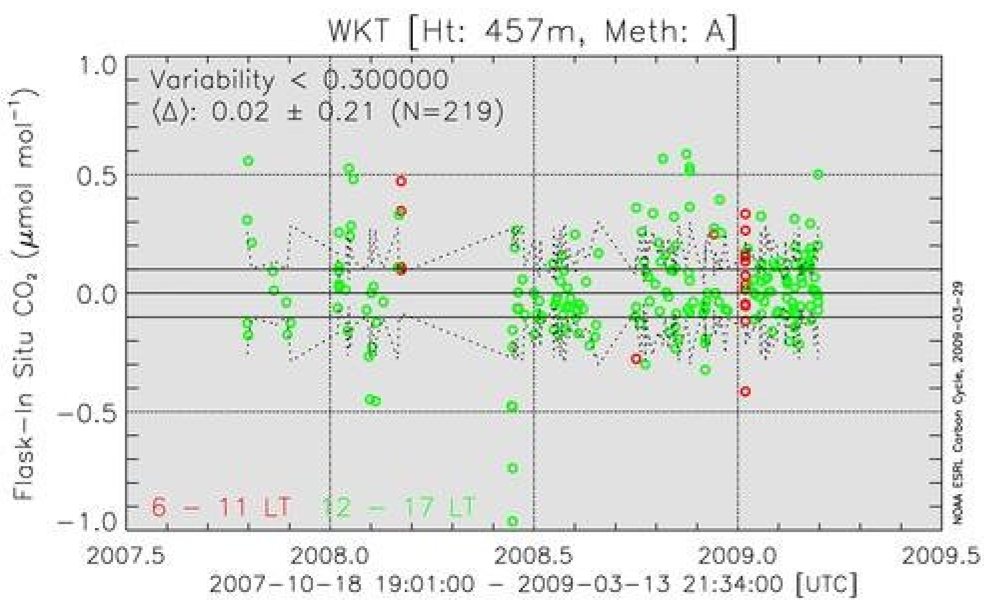

Figure 1. Flask versus *in situ* comparison for the WKT site. Data have been selected for periods when data from the *in situ* analyzer indicate low atmospheric variability (1s < .3ppm over 60 minutes). The mean difference is 0.02 +/- 0.21ppm for 219 samples. The colors indicate time of day as described in the lower left corner of the graph.

Interpreting Dense CO_2 Measurements: Ensemble Filters Vs. Variational Data Assimilation

D. Baker

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With the recent launching of the GOSAT satellite, atmospheric CO_2 concentration measurements of sufficient density to estimate sources and sinks on regional scales should soon be available. This presents a computational challenge: how can we make the most use of the data (by solving for surface fluxes or carbon model parameters the finest spatial and temporal resolution as the data allow) without overwhelming our computational resources? Two types of methods have been targeted to do this: ensemble filtering methods, such as the fixed-lag (ensemble) Kalman smoother (EnKF) used in CarbonTracker, and variational data assimilation methods, which use an approach similar to the "4D-Var" methods of numerical weather prediction. Here, we compare the relative merits of the two approaches. In terms of the total computational effort, the variational methods are more efficient, by a factor proportional to the number of flux time steps retained in the EnKF state. However, because the EnKF is highly parallelizable, it should have the edge in terms of run time. Both methods provide a similar low-rank estimate of the flux covariance; in terms of the "square-root" of the covariance, the ensemble methods compute a single column per ensemble member, the variational methods a single column per iteration of the optimization method. The accuracy of the variational approach has been verified using simulation studies; here we use similar simulations ("OSSEs") to quantify the ability of satellite measurements to improve surface CO_2 flux estimates (Figure 1). Similar studies should be done to validate the ensemble methods: it is not at all clear that they will do as well, given that there is no iterative refinement of the estimate with respect to the data. Finally, we describe a resolution-refinement approach that will allow the variational method to estimate fluxes at resolutions of 1x1 deg (lon/lat) and finer, globally; preliminary simulation results are shown.

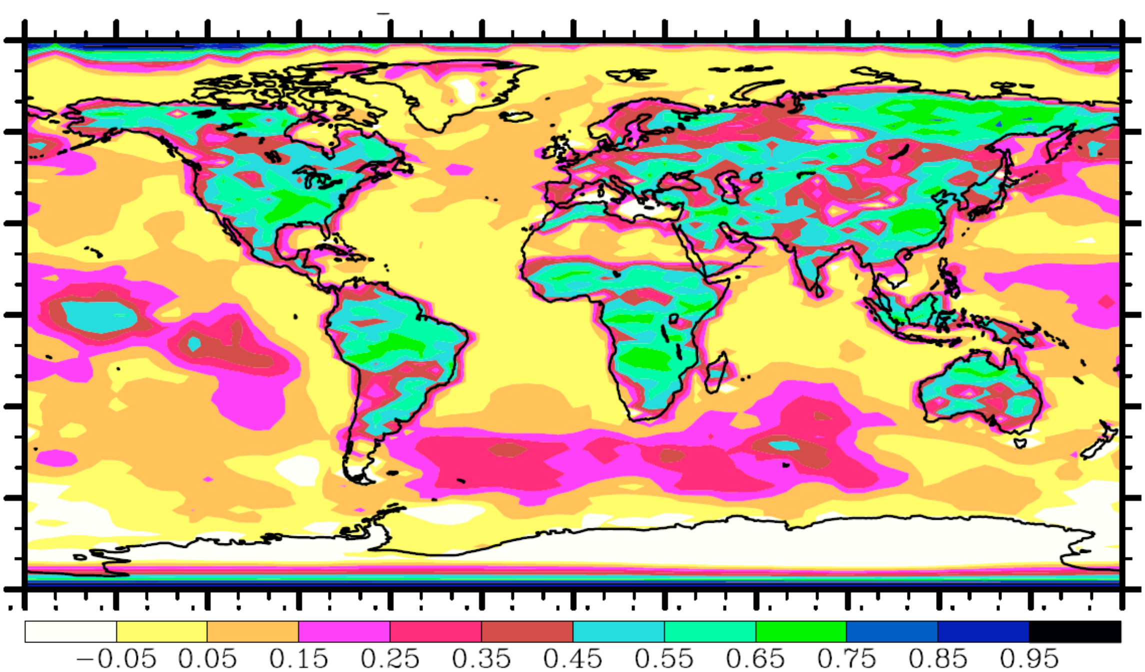

Figure 1. Improvement in weekly land and ocean CO_2 flux estimates at 5x2 deg (lon/lat) expected from measurements from the Orbital Carbon Observatory (OCO) over a prior guess taken from process models, as simulated using our variational data assimilation system after 25 iterations of the minimization. The reduction in the uncertainty due to only random errors is given; biases and other systematic error sources degrade the results further.

High-Latitude Carbon Exchange Estimated from Co-Variation of CO_2 and Potential Temperature

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Simulations of the vertically averaged mixing ratio of carbon dioxide, show both weak seasonal cycle amplitude and weak spatial and temporal variations, influenced by variations in local exchanges with the surface. In contrast, observations made *in situ* from aircraft and by infrared solar spectrometry from the ground show that summertime variations over North America are much larger than previously thought. We show that these variations result from synoptic weather systems that advect large-scale gradients in free-tropospheric CO_2. Simulations with the AM2 general circulation model show that the observed variations can be accounted for if the amplitude of northern hemisphere land exchange exceeds 35 Pg annually, a flux much larger than indicated by biosphere models. Because such biosphere models are used in inversion calculations to determine long-term changes in carbon stocks on land from measurements of CO_2 concentrations, our findings imply revised estimates of CO_2 sources and sinks.

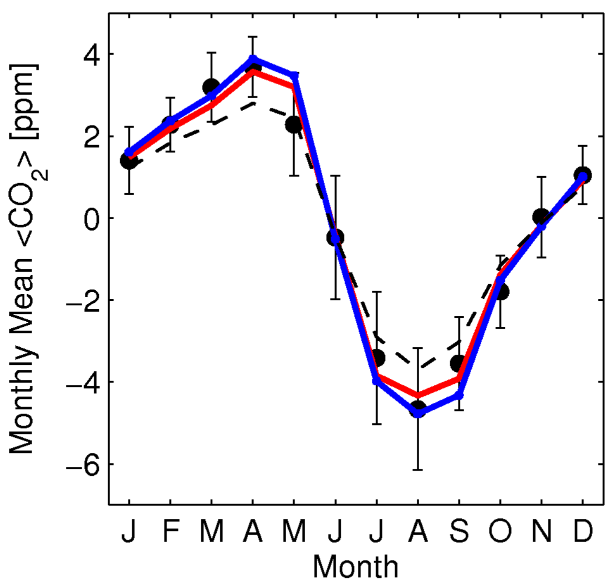

Figure 1. Monthly mean, detrended from ground-based spectrometer (black circles), plotted with monthly mean from AM2 using CASA as boundary conditions (black dashed line), and from AM2 using northern land fluxes enhanced by 30% (red) and 40% (blue). Seasonal cycle is underestimated by 25% using CASA atmosphere-biosphere exchange.

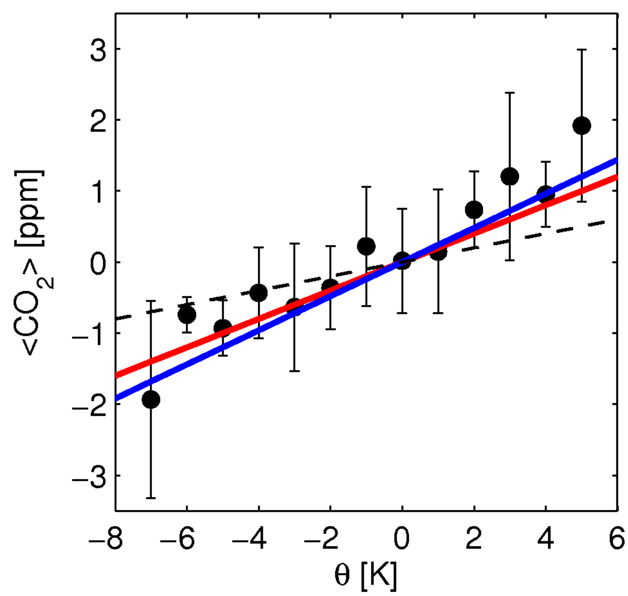

Figure 2. July-August filtered plotted against filtered 700 hPa potential temperature (θ). Symbols as in Figure 1. The relationship provides an estimate of the north-south gradient during the growing season. Simulations driven by CASA biosphere-atmosphere exchange underestimate the gradient by a factor of 2. For both seasonal cycle amplitude and implied north-south gradient, simulations best match the observations when biosphere-atmosphere fluxes are enhanced at high northern latitudes.

Observing Regional CO_2 Plumes with an Airborne Differential Laser Absorption System

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A new laser-based technique for quantitative airborne monitoring of carbon dioxide (CO_2) column amounts has been developed, and extensive testing has shown that this system provides high-precision CO_2 column measurements with RMS error less than 1.5 ppm. This unique airborne development and test environment combines a fiber laser-based instrument designed and developed jointly by ITT and NASA Langley Research Center (LaRC) to measure CO_2 column amounts, with collocated NIST-traceable *in-situ* measurements of atmospheric CO_2 profiles, surface/atmospheric temperature, moisture and pressure information obtained from rawin/radiosonde launched in conjunction with the flight campaigns, and validated line-by-line radiative transfer (RT) modeling tools. This not only provided assessment of instrument performance, but also a robust method for instrument calibration. Collocated instrument and *in-situ* measurements provide a natural mechanism for preliminary instrument calibration, and enable extending the test flight data to demonstrate the preliminary performance of this instrument's capability to measure/monitor changes in CO_2 on a regional scale. In this work, we outline the data collection and calibration methods, and demonstrate how this measurement technique can be used to measure/monitor changes in CO_2 concentrations on a regional basis over a mixed terrain and environmental conditions. The figure below illustrates calibrated science data obtained as part of our extensive April 2008 flight campaign over the Norfolk/Suffolk, VA area. This region has diverse terrain/environmental settings, and includes both terrestrial/oceanic settings as well as rural/urban environments. This figure demonstrates dramatic localized changes in CO_2 column amounts and CO_2 plumes based on small scale changes in terrain/environment. Future campaigns will be designed to further develop this analysis, and may include incorporating these data into high-fidelity region scale modeling of CO_2 sources and sinks.

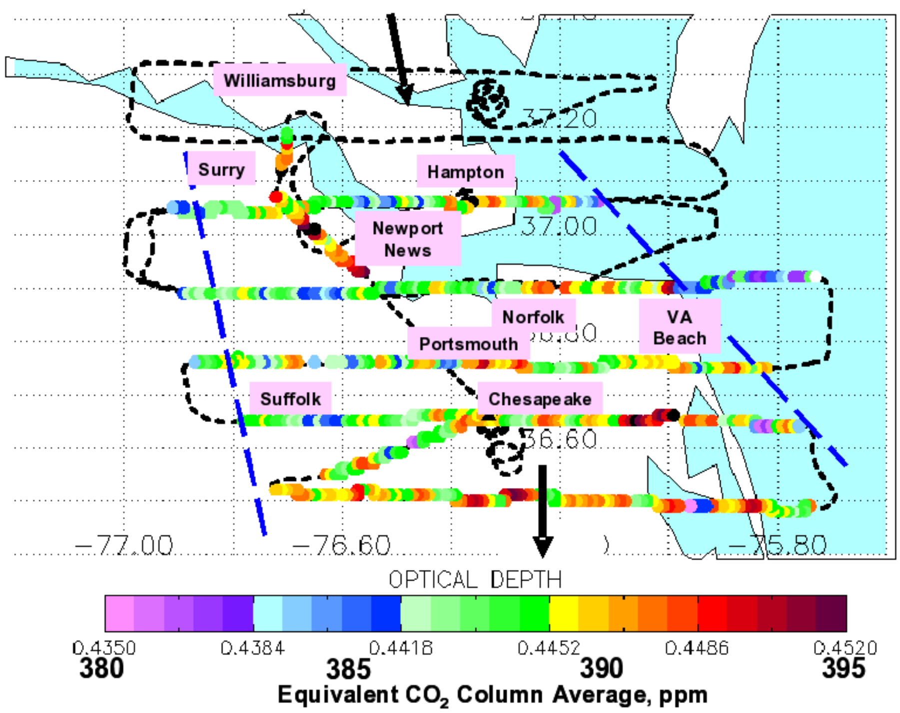

Figure 1. Observed variation in CO_2 column amounts from airborne laser absorption measurements acquired over the Norfolk/Suffolk, VA region in April 2008. This figure illustrates flight path and individual CO_2 column measurements that show distinct localized variations in CO_2 concentrations or plumes.

On-Road Study of Colorado Front Range Greenhouse Gases Distribution and Sources

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The Global Monitoring Division and Chemical Sciences Division of the NOAA Earth System Research Laboratory have teamed up over the summer 2008 to experiment with a new measurement strategy to characterize greenhouse gases distribution and sources in the Colorado Front Range. Combining expertise in greenhouse gases measurements and in local to regional scales air quality study intensive campaigns, we have built the 'Hybrid Lab'. A continuous CO_2 and CH_4 cavity ring down spectroscopic analyzer (Picarro, Inc.), a CO gas-filter correlation instrument (Thermo Environmental, Inc.) and a continuous UV absorption ozone monitor (2B Technologies, Inc., model 202SC) have been installed securely onboard a 2006 Toyota Prius Hybrid vehicle with an inlet bringing in outside air from a few meters above the ground. To better characterize point and distributed sources, air samples were taken with a Portable Flask Package (PFP) for later multiple species analysis in the lab. A GPS unit hooked up to the ozone analyzer and another one installed on the PFP kept track of our location allowing us to map measured concentrations on the driving route using Google Earth. The Hybrid Lab went out for several drives in the vicinity of the NOAA Boulder Atmospheric Observatory (BAO) tall tower located in Erie, Colorado and covering areas from Boulder, Denver, Longmont, Fort Collins and Greeley. Enhancements in CO_2, CO and destruction of ozone mainly reflect emissions from traffic. Methane enhancements however are clearly correlated with nearby point sources (landfill, feedlot, natural gas compressor ...) or with larger scale air masses advected from the NE Colorado, where oil and gas drilling operations are widespread. The multiple species analysis (hydrocarbons, CFCs, HFCs) of the air samples collected along the way brings insightful information about the methane sources at play. We will present results of the analysis and interpretation of the Hybrid Lab Front Range Study and conclude with perspectives on how we could adapt the measurement strategy to study more quantitatively GHG anthropogenic emissions in Denver Basin.

Figure 1. NOAA ESRL Hybrid Mobile Lab for the Summer 2008 Front Range Emissions Study.

Continuous Tower-Based Tropospheric Ozone Measurements

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As well as its role as a greenhouse gas, tropospheric ozone plays a pivotal part in the chemistry of the lower atmosphere. Photochemical and chemical reactions involving ozone drive many nocturnal and diurnal chemical processes. Metropolitan area ozone concentrations are frequently monitored, but continuous measurement of background concentrations found in rural areas is also necessary. In order to understand background levels and influences of local ozone sources, we installed two monitors at NOAA's Boulder Atmospheric Observatory in Erie, Colorado. Continuous measurements were taken at the surface and at a 300-meter height on the tower starting in July 2008. In combination with concurrent wind and humidity measurements, we investigate diurnal, monthly and seasonal patterns from July 2008 – May 2009. We employ HYSPLIT, a dispersion model, to investigate sources of high ozone events during this period. Additionally, profiles of various constituents measured at the tower are compared.

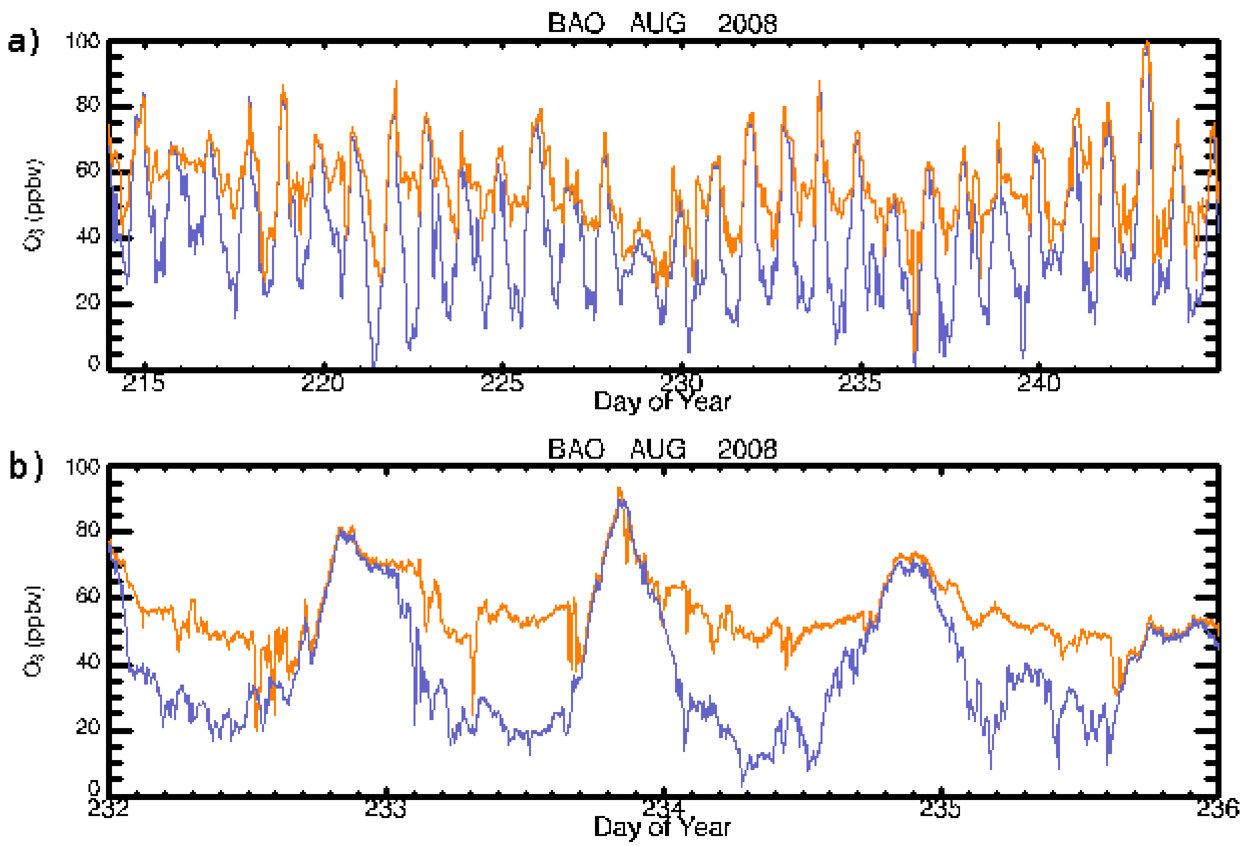

Figure 1. Measurements of ozone mixing ratios from UV-absorption instruments at surface (blue) and 300 m (orange). Shown in a) is the hour-averaged diurnal variation during August 2008 and b) shows the 5-minute averages of August 20 - 24, 2008. The spread of mixing ratio values at night reveals that the tower-mounted instrument is out of the nighttime boundary layer.

Statistical Analysis and Estimation of the External Effects on the Total Ozone Field Over Russia in 1973-2007

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Thirty-five years of ground-based data are used to study the external effects on the total ozone (TO) over Russia, averaged seasonally (December-March, June-August) and annually. Discriminant and spectral analysis of TO time series is performed to isolate and distinguish the separate effects of the eleven-year solar cycle, the Quasi-biennial Oscillation (QBO), the Arctic oscillation, the El Nino-Southern oscillation (ENSO), the winter Arctic lower stratosphere temperature interannual variations on TO fields and to identify the spatial differences in the analyzed processes. During the winter months, the negative AO, the warm stratosphere and the westerly QBO years are statistically well-separated from the years when all the factors happen to be in their opposite phases. Being of roughly comparable difference between phases (35 DU, 28 DU, 26 DU respectively) these factors constitute the dominant effects on the ozone layer in the winter hemisphere. Spectra as well as discriminants of the June-August total ozone indicate a strong influence of the QBO and the eleven-year solar cycle in the summer months with the QBO prevailing in the Asian regions. All the results are significant at 95% level as confirmed by the Monte-Carlo test. The discrimination is performed better at the lower level of the other intervening factors, thus relatively small effects of ENSO and Solar cycle came out to be statistically indeterminate in the winter months with many underlying processes at work. Nevertheless discriminant analysis as described by Schneider and Held, 2001, is a powerful method of multivariate analysis which allows both temporal and spatial representation of the data, while simpler methods, e.g. Student's t-test, could not yield quantitative results of the same range. The physical grounds of the statistically established effects are proposed and discussed.

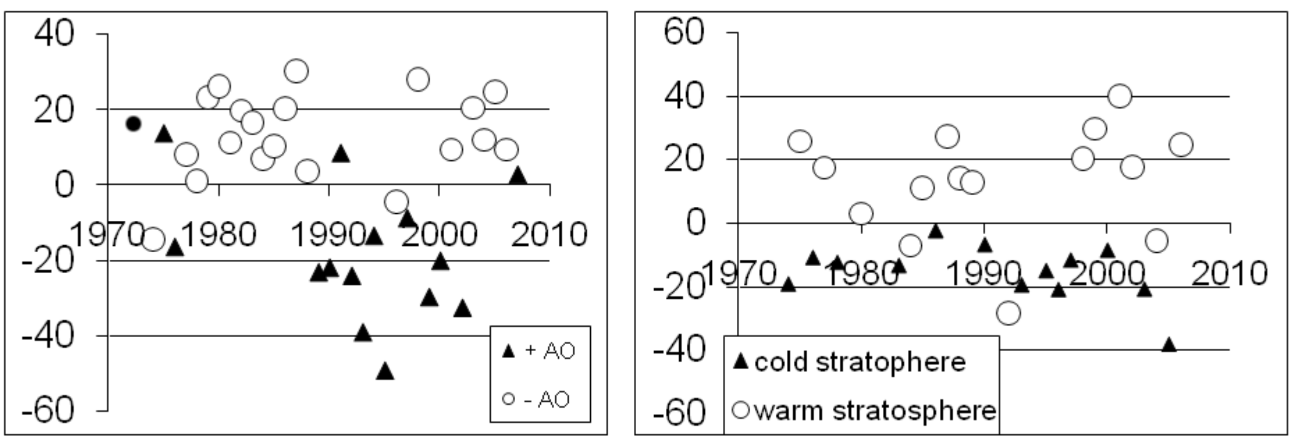

Figure 1. Canonical variates (DU) of Total Ozone time series for Arctic Oscillation phases and stratosphere temperature groups.

Long-Term Ozone Trends in Umkehr Measurements at Japanese Stations

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Umkehr observations have been made routinely at Japanese stations at Sapporo, Tsukuba, and Naha, and at the Antarctic station, Syowa, for more than 50 years. The discontinuous gaps in Japanese Umkehr data record have been associated with instrument replacements. Therefore, N-value data were recently reevaluated based on instrument intercomparisons. The data analysis revealed systematic errors that depend on solar zenith angle, total ozone, and other instrumental factors. The UMK04 ozone profile retrieval algorithm is applied in the processing of all reevaluated N-value time-series. We present a long-term ozone trend determined from the newly re-processed Umkehr ozone profiles. The long-term trend in upper stratospheric ozone is discussed in this paper. Long-term variations of the ozone amount derived by UMK04 algorithm in the combined 8 and 9 layers at Sapporo, Tsukuba, Naha and Syowa are shown in the Figure 1. Linear trends in two separate periods 1970 (or 1977) -1996 and 1996-2008 are also shown for each station. Trend analyses suggest a significant decrease in the upper stratosphere over Japan during the 1980s. The upper stratospheric ozone levels at Tsukuba Station have shown a steady increase at 5%/decade rate after 1996. At the same time, a 7.7%/decade decrease in ozone is found in Umkehr data taken at Sapporo Station, which indicates an even stronger ozone depleting rate as compared to ozone depletion rates prior to 1996. Over the Antarctic station Syowa, upper stratospheric ozone has been at a low level since 1990s. Especially low values can be seen in the last few years. Observed difference in the upper stratospheric ozone changes may be reflecting the latitude dependence of ozone depletion.

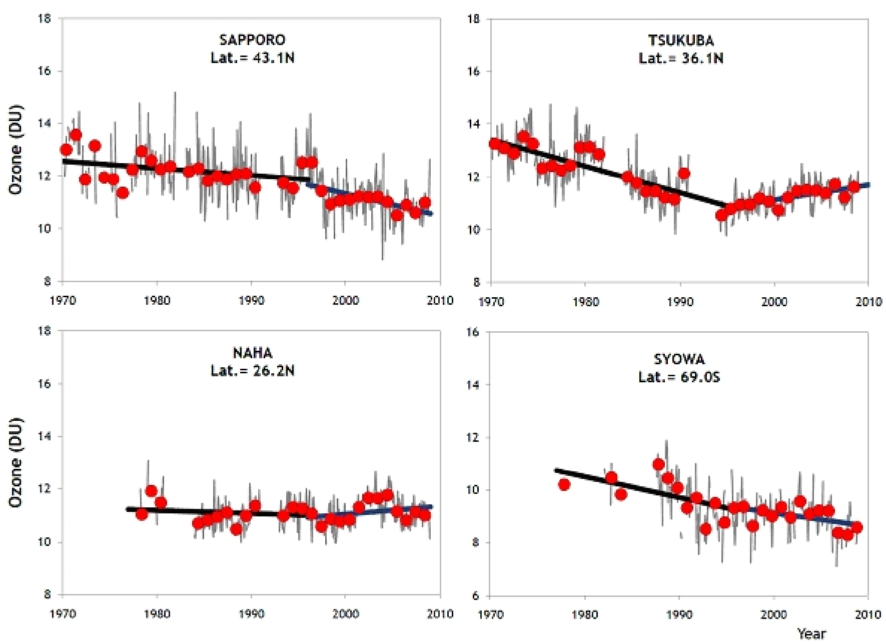

Figure 1. Long-term variations of ozone amount in 8+9 layers. Linear trend fit is derived after removing effects such as solar activity, QBO, and atmosphere turbidity. A gray line shows monthly average and red circle shows average of the year. Solid lines show linear trends from 1970 (or 1977) to 1996 and from 1996 to 2008. Periods interfered by volcanic eruptions, El Chichon (1982-1983) and Mt. Pinatubo (1992-1993), were removed from the analysis.

Boundary Layer Ozone Depletion Events Measured by Ozonesondes at Barrow, Alaska in 2009

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NOAA ESRL Global Monitoring Division, in partnership with Environment Canada, launched 25 ozonesondes at the Barrow Observatory from March 12 to April 15, 2009 as part of the international multidisciplinary study called OASIS (Ocean - Atmosphere - Sea Ice - Snowpack). During polar sunrise, the icepack is considered to be a major source of bromine that leads to rapid ozone depletion events within the boundary layer. Surface ozone monitors at Barrow Observatory have recorded these events since the site was established in 1973. During March and April, ozone can quickly drop from a typical 30 to 40 ppbv to 0 to 10 ppbv for a few hours or 1-2 days. However, the vertical extent is not well known. Therefore, ozonesondes were launched every other day and as often as daily during ozone depletion events to determine the height at which the low ozone occurs over the snow-packed region. Figure 1 shows a major event on March 12, 2009 when near-zero ozone was measured up to 300 meters above the surface. In sharp ozone transitions as these, the actual ozone gradient is much sharper than the ozonesonde sensor can measure due to the typical rise rate (4-5 m/s) of the balloon and slow response time (1/e of 20 seconds) of the sonde sensor. Therefore new methods to slow the rise rate of the balloon to 0.5 to 2 m/s were used to obtain a more accurate ozone transition region.

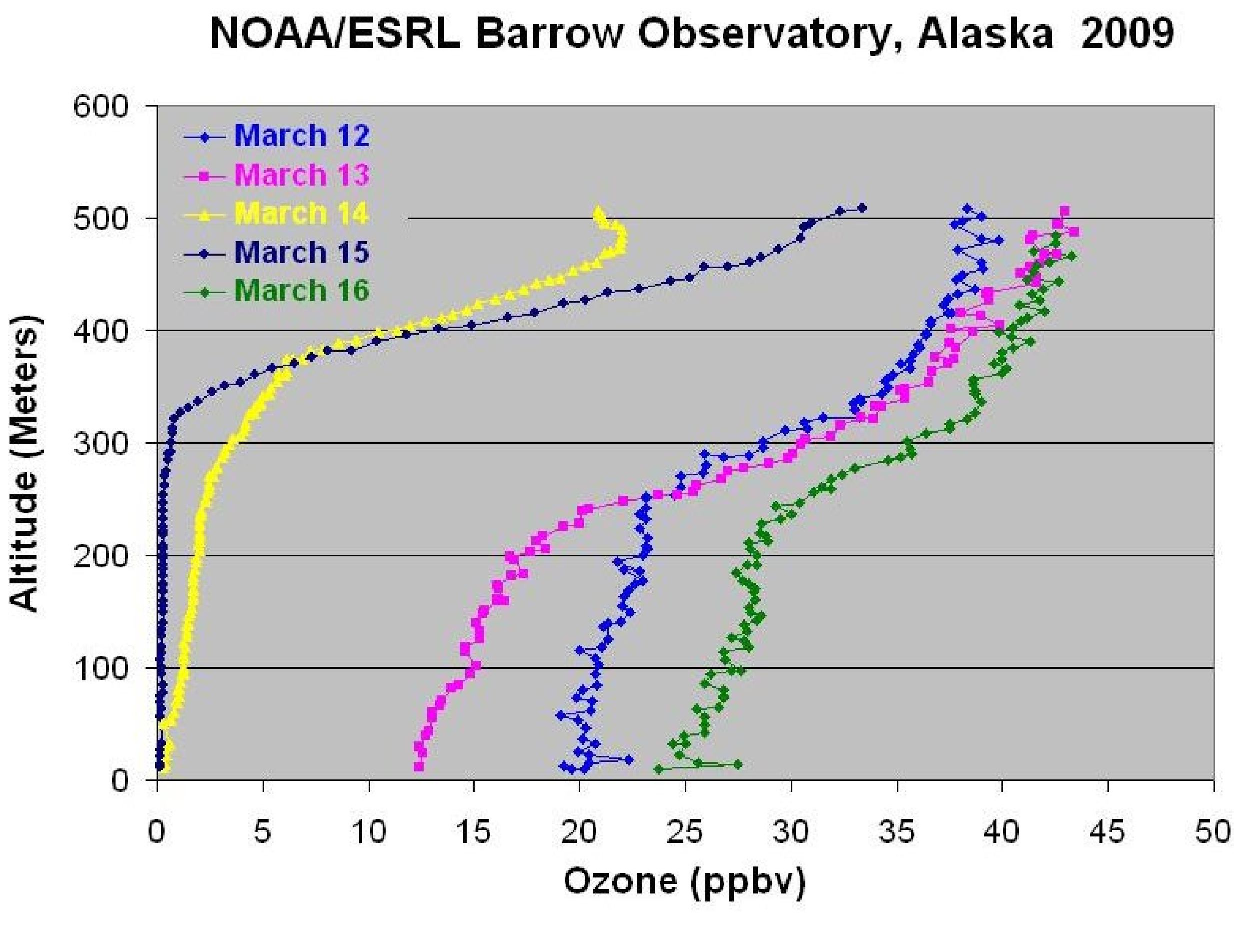

Figure 1. Ozonesonde profiles (surface to 500 meters) showing near-zero ozone within the boundary layer during an ozone depletion event.

Boulder and the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)

D. Hurst[1], E.G. Hall[1], A.F. Jordan[1], B.J. Johnson[2], J. Wang[3] and S.J. Oltmans[2]

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Upper air temperature, humidity and wind records from existing global observing systems have too many inconsistent uncertainties to be useful in climate models and trend analyses. These observations have predominantly been made in support of weather research and forecasting, not to construct self-consistent, longer-term data records. The concept of the GRUAN is built upon the need for improving the precision, accuracy and long-term stability of climate observations made by the existing global upper air network (GUAN) such that high-quality, internally consistent climatologies can be produced. Boulder has been proposed as one of about 10 initial GRUAN sites around the globe, thanks to the many high-quality, long-term measurement programs in the area. First and foremost are NOAA ESRL's weekly soundings of temperature, pressure, and ozone or water vapor (or both) using balloon-borne instruments launched at the NCAR Marshall field site. ESRL also maintains two nearby Baseline Surface Radiation Network sites, Table Mountain and the Boulder Atmospheric Observatory (BAO), which measure all GRUAN surface radiation variables. These existing observation systems and the experienced scientific teams who operate and maintain them make Boulder an ideal candidate reference site. The GRUAN's strict criteria for calibration, intercomparison and validation of measurements will require some important additions to ESRL's measurement programs at these sites. The radiosondes currently in use will soon be augmented with the "best currently available technology" production radiosondes and each sounding sensor will be "ground truthed" immediately before launch. GPS retrievals of precipitable water vapor and microwave radiometric profiles of temperature and water vapor will enable intercomparison and validation of upper air measurements.

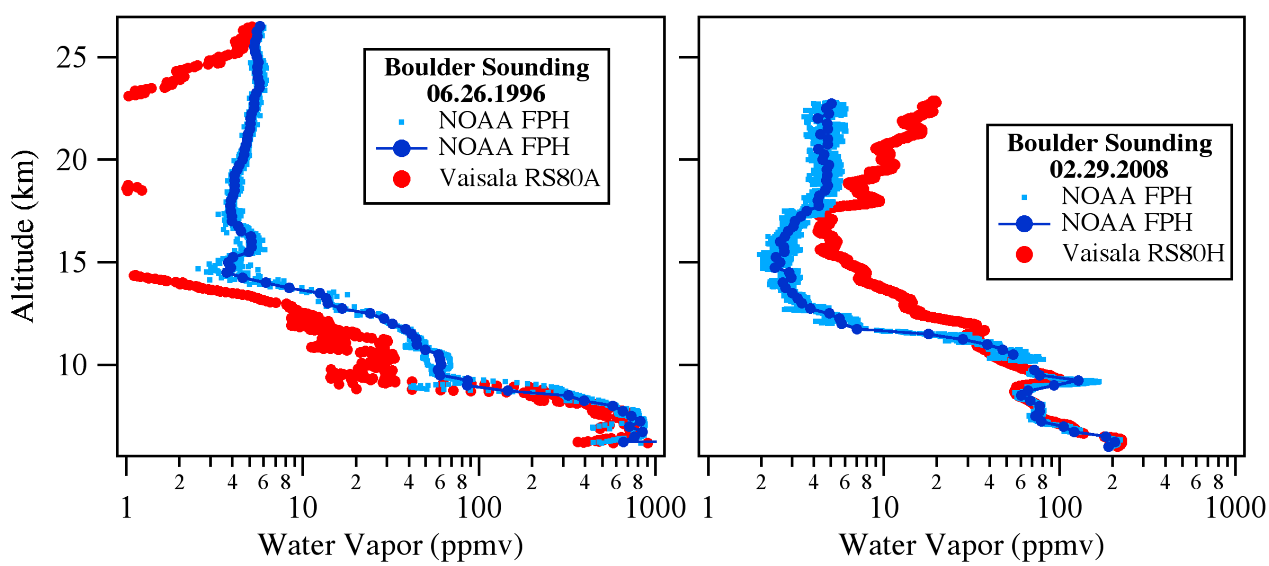

Figure 1. Water vapor mixing ratio profiles from NOAA frostpoint hygrometers (cyan and blue) and Vaisala RS80 radiosondes with A- and H-Humicap sensors (red) over Boulder, CO. The Vaisala Humicap sensors are known to be prone to measurement errors arising from contamination and degradation during storage, have increasingly long response times at cold temperatures, and typically don't respond accurately to frostpoints lower than -65°C.

Long-Term Monitoring and Trends of Halocarbons

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In the mid-1970s, the fledgling Geophysical Monitoring for Climate Change (GMCC) program started and made a commitment to measure and monitor trace gases. As GMCC grew into a division and then a premier laboratory (NOAA ESRL), the trace gas measurement programs evolved into groups with separate programs. Today's Halocarbons and other Atmospheric Trace Species (HATS) group measures 40+ atmospheric trace gases via flasks or *in situ* methods at surface sites and aboard airborne platforms. There are several instruments and programs that have made measurements of the same gases such as chloroflourcarbon-11 (CFC-11), CFC-12 and nitrous oxide (N_2O). Multiple measurements of the same gases can sometimes lead to confusion when determining what measurement to use for analysis.

This presentation will provide assimilated global trace gas data from several measurement programs including flasks and *in situ* methods. Many of these measurements are used in the NOAA ESRL products, Annual Greenhouse Gas Index (AGGI) and the Ozone Depleting Gas Index (ODGI). This presentation will also report on recent trends in the most abundant halogenated gases.

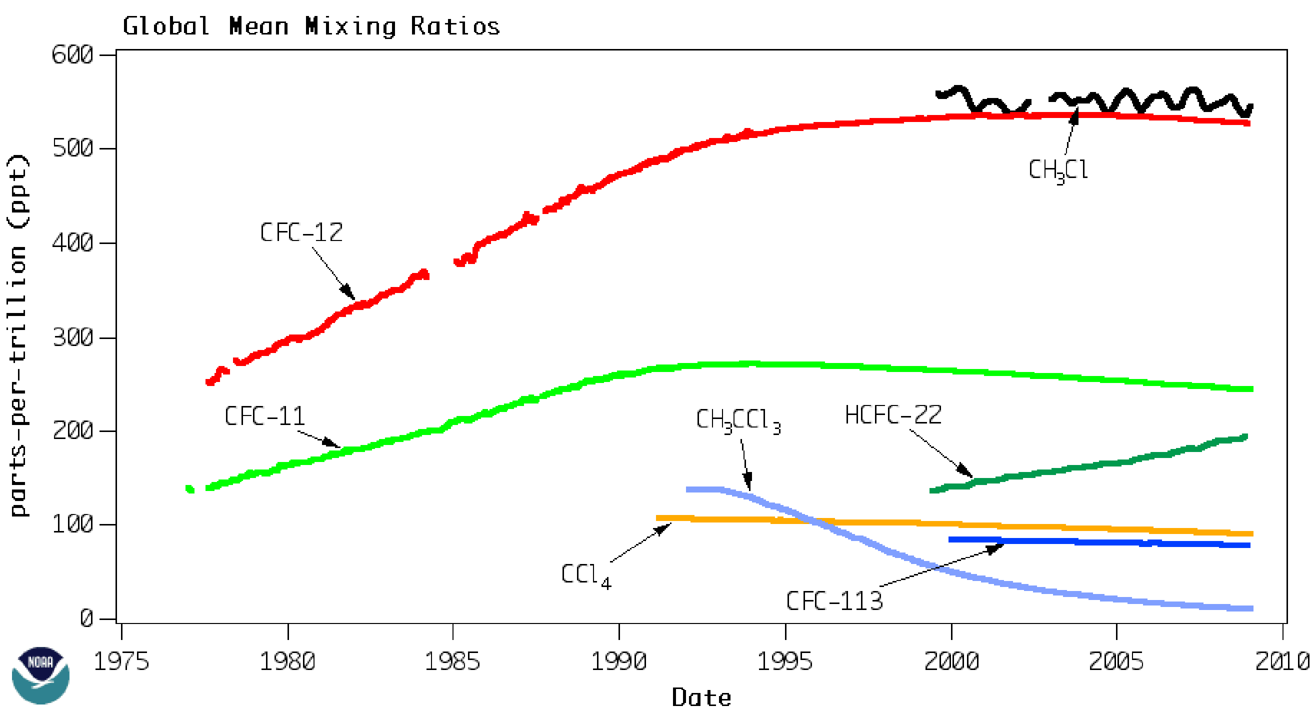

Figure 1. Four measurement programs were combined to calculate global mean mixing ratios for CFC-11 and CFC-12. As the trace gas programs evolved more halogenated gases were added in the mid to late 1990s.

A Comparison of Seasonal Cycles in Nitrous Oxide Among Different Monitoring Networks

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The seasonal cycle of atmospheric nitrous oxide (N_2O) reflects stratospheric, transport and biogeochemical influences. With peak-to-trough amplitudes well under 1% of the mean tropospheric mixing ratio, N_2O seasonal cycles are difficult to detect. NOAA CCGG provides by far the largest global network of atmospheric N_2O measurements, but tends to show larger seasonal cycles in the southern hemisphere than other monitoring networks, including NOAA HATS, AGAGE and CSIRO. This poster examines possible reasons for the differences in N_2O seasonal cycles among networks and the likelihood of separating transport and stratospheric influences on these cycles from biogeochemical signals.

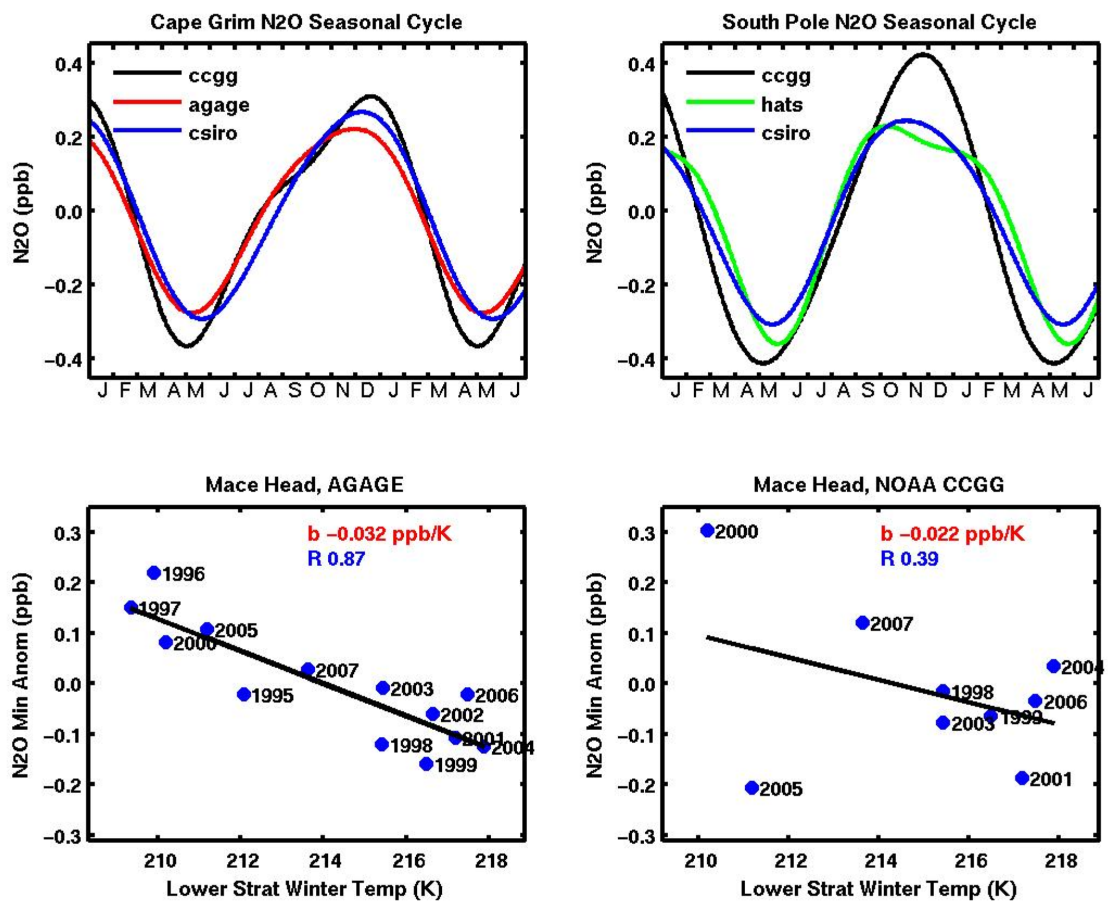

Figure 1. Mean seasonal cycles in N_2O derived from harmonic fits to detrended data from three different monitoring networks at: a) Cape Grim Tasmania, 1997-2003, b) South Pole, 2001-2007, c-d) N_2O seasonal minimum anomaly at Mace Head, Ireland plotted against mean January-March 100 hPa 60-90N temperature, c) AGAGE data from 1994-2007, d) NOAA CCGG data from 1998-2007. Since wintertime lower stratospheric temperature is a proxy for the strength of the seasonal descent of N_2O-depleted air from the stratosphere, with greater descent occurring in warm years, panels c-d suggest that interannual variability in N_2O seasonal cycles may primarily reflect stratospheric rather than biogeochemical influences at some stations and that the detection of these influences may differ among networks.

New Estimates of Global Sulfur Hexafluoride Emissions Using AGAGE and NOAA Measurements

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We present a 'top-down' estimate of sulfur hexafluoride (SF_6) emissions for 2004 – 2006. A global emission rate of 5.6 ± 0.4 Gg/yr is derived, which is approximately 9% higher than predicted by the Emissions Database for Atmospheric Research for the year 2000 (EDGAR v3.2). The sensitivity of daily SF_6 mole fractions to changes in emission rate from ten source regions was found using the Model for Ozone and Related chemical Tracers (MOZART v4.5 at 1.8x1.8 degree resolution). These sensitivities were used with measurements from the Advanced Global Atmospheric Gases Experiment (AGAGE) and NOAA flask and *in-situ* networks to optimally constrain emissions. Preliminary inversion results indicate that emissions from Eastern Asia and the United States may be underestimated in the inventory, whilst Europe's emissions may be overestimated.

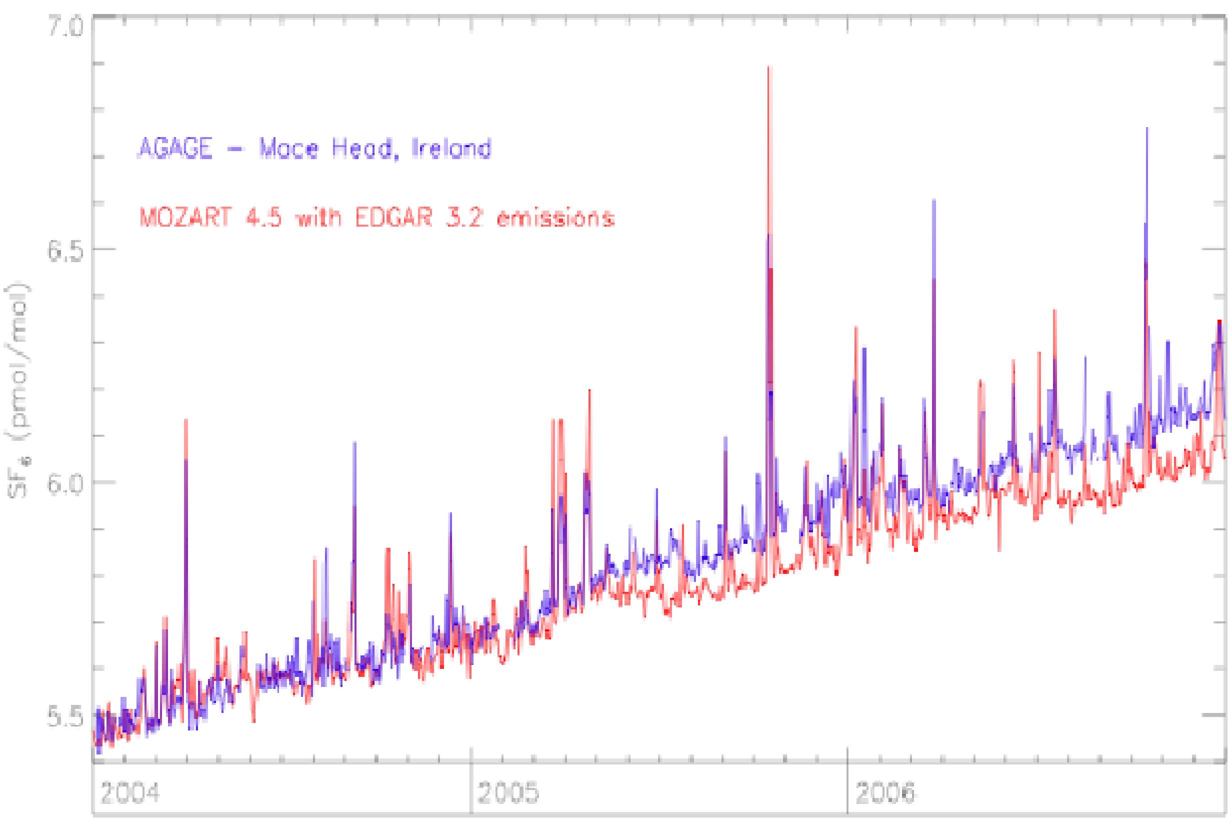

Figure 1. Daily mean AGAGE SF_6 mole fraction at Mace Head, Ireland (blue line), and simulated mole fraction at the same location using MOZART 4.5 with EDGAR 3.2 emissions (red line), 2004 - 2006. The figure shows that the model captures the variability at this site well. However, an underestimate of the rate of increase in the modeled Northern hemisphere (NH) background can be seen, consistent with an underestimate of the NH emission rate in the inventory. Pollution events are generally over-estimated by the model, which may suggest an over-estimate of nearby (European) emissions.

Isotopic Constraints on the Global Budget of Atmospheric Nitrous Oxide: Analysis of Recent Data

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We developed a simple box model for nitrous oxide (N_2O) that is based on laboratory kinetics measurements and constrained to reproduce the age of air in the stratosphere from the Caltech/JPL two-dimensional model of the terrestrial atmosphere. The model assumes that the primary sources of N_2O are the land, the ocean and agriculture, and the primary sink is destruction in the stratosphere. Additional N_2O sources include those from rivers, estuaries and coastal zones as well as fossil fuel combustion and industrial processes, as recommended by IPCC [2007]. The model also explores the consequences of a climate-related acceleration of the Brewer-Dobson circulation that transports N_2O from the troposphere to the stratosphere. The model includes all the commonly studied isotopologues and isotopomers of N_2O and can account for most of known observations. These observations include the abundances and trends of the isotopologues and isotopomers of N_2O since the Pre-Industrial Era. Isotopic analysis narrows the uncertainty range of the model budget. See Figs 1 and 2.

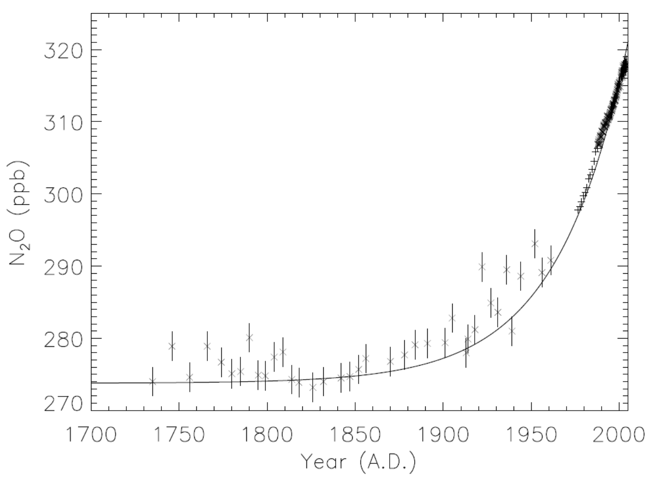

Figure 1. Comparison of N_2O concentrations from 1700 to the present between the Baseline Model (solid line) and data. Crosses: Machida et al. [1995]. Khalil and Rasmussen [1992]. More recent data from NOAA CMDL.

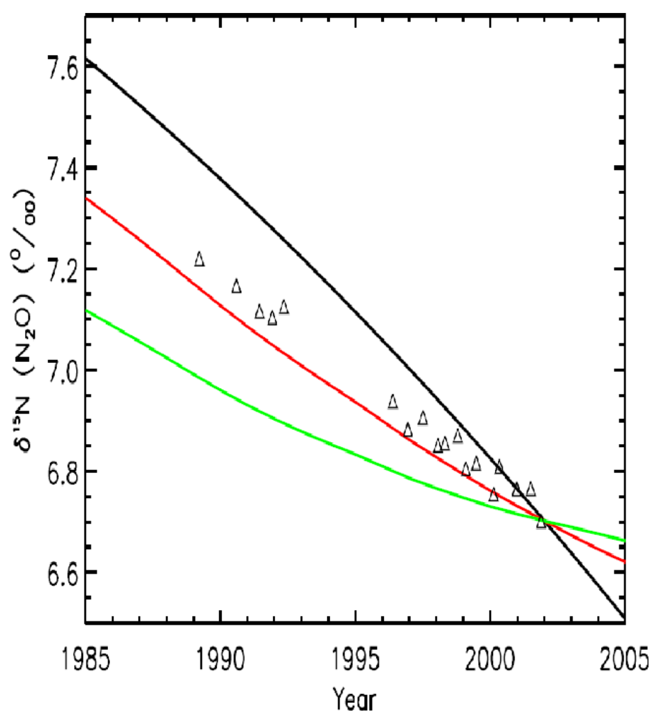

Figure 2. Comparison of specific isotopic change for $\delta^{15}N(N_2O)$ between the Baseline Model (black line), Standard Model (red line) and Extended model (green line) and data (Roeckmann and Levin 2005) from 1990 to 2002 A.D.

Improvements to the NOAA ESRL GMD Cryogenic Frostpoint Hygrometer (FPH) – New Digital Control

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Research and development started 4 years ago in February 2005 transforming the historic analog NOAA cryogenic FPH into a digitally-controlled instrument. The basic optical and thermodynamic fundamentals still used in today's hygrometer were developed in 1956 and have undergone few major changes over the years. The electronics have changed as necessary and as parts became obsolete. This poster will focus on the improvements the new digital hygrometer boasts over its predecessor in weight, performance, and cost. Adding a microcontroller to the electronics increases the versatility, allows for advanced measurement techniques, and creates new complex control schemes that were unrealistic for the older analog hygrometer. The analog instruments were flown monthly at Boulder from 1980 and at Lauder, New Zealand from 2004 until early 2008 when both sites began launching the new digital NOAA FPH. Comparisons of NOAA FPH data with balloon-borne data from the University of Colorado Cryogenic Frostpoint Hygrometer (CU-CFH) and vertical retrievals from satellite-based measurements from the NASA Earth Observing System (EOS) Microwave Limb Sounder (MLS) show good agreement. This instrument remains a work in progress and there are many future plans and improvements that will be addressed.

Figure 1. Emrys Hall about to launch one of the digitally controlled NOAA ESRL GMD cryogenic frostpoint hygrometers with an attached ozonesonde from Marhsall Field Site near Boulder, CO.

On the Definition of a European Baseline for Climate Altering Halogenated Gases

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Starting from 2002, 27 halogenated greenhouse gases are continuously monitored at the atmospheric research station "O. Vittori" located on the top of Monte Cimone, Northern Apennines, Italy (2165 m asl), using a GC-MS instrument equipped with an automating sampling and enrichment unit, allowing us to perform a chromatographic run of ambient air every second hour. That in the frame of the SOGE (System for Observation of halogenated Greenhouse gases in Europe) network, an integrated system based on a combination of observations and models. One of the aims of the network is to provide long-term European observations of halogenated greenhouse gases in order to assess atmospheric baseline trends and annual growth rates. Establishing the baseline is particularly challenging in a station like Monte Cimone characterised by a complex meteorological and source field. The approach proposed is based on the identification of the lowest concentration values in a given temporal range to which a Δc representing variation due to instrumental error is added. This approach has been tested using data from a less complex situation (sea level, not influenced by strong emission fields) and the obtained baselines have been compared against those already determined for that specific site using a different approach available in the open literature. Trends are evaluated by using a non-linear regression function, able to take into account both annual and seasonal variation. A new regression function relating the seasonal amplitude to the concentration of the investigated compound is proposed. The new regression function gives better R2 values for compounds characterized by a shorter lifetime.

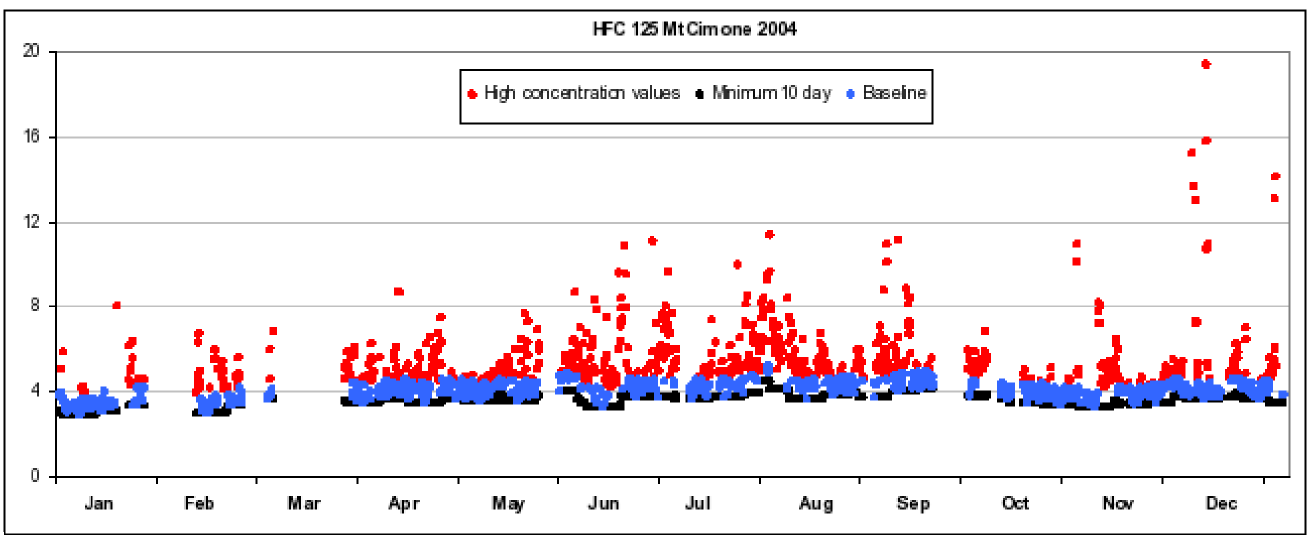

Figure 1. One year of continuous measurements of HFC-125 at Monte Cimone.

Snapshot of Atmospheric Trace Gases "Pole to Pole" – Results from the HIPPO1

B.R. Miller[1], F. Moore[1], L. Miller[2], S.A. Montzka[3], E. Atlas[4], J.B. Miller[1], B.H. Vaughn[5], S.E. Michel[5], P. Lang[3], K. Sours[1], C. Sweeney[1], D. Guenther[1], S. Wolter[1], J. Higgs[2], S. Davis[1], D. Nance[1], E. Dlugokencky[3], P. Novelli[3], T. Conway[3], P. Tans[3], J.W. Elkins[3] and S. Wofsy[6]

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Results from flask samples taken during the first mission (January 2009) of a planned five-mission "Pole to Pole" campaign provide an unprecedented snapshot view of ~40 atmospheric trace gas distributions throughout much of the troposphere. Using the Carbon Cycle Greenhouse Gases group's programmable flask packages, 233 whole air samples were acquired and analyzed for CO_2, CO, CH_4, N_2O, H_2, SF_6, non-methane hydrocarbons, halocarbons and sulfur compounds. Trace gas distribution patterns derived from the interplay of transport, chemistry and/or source/sink distributions are evident across hemispheric scales and through atmospheric regimes that include the open Pacific Ocean and North America and from near-surface (200m) up to regions of stratospheric influence (14,400m). The multitude of measured atmospheric compounds, spanning a wide range of lifetimes, growth rates and source/sink distributions, provide insight into chemistry and transport processes.

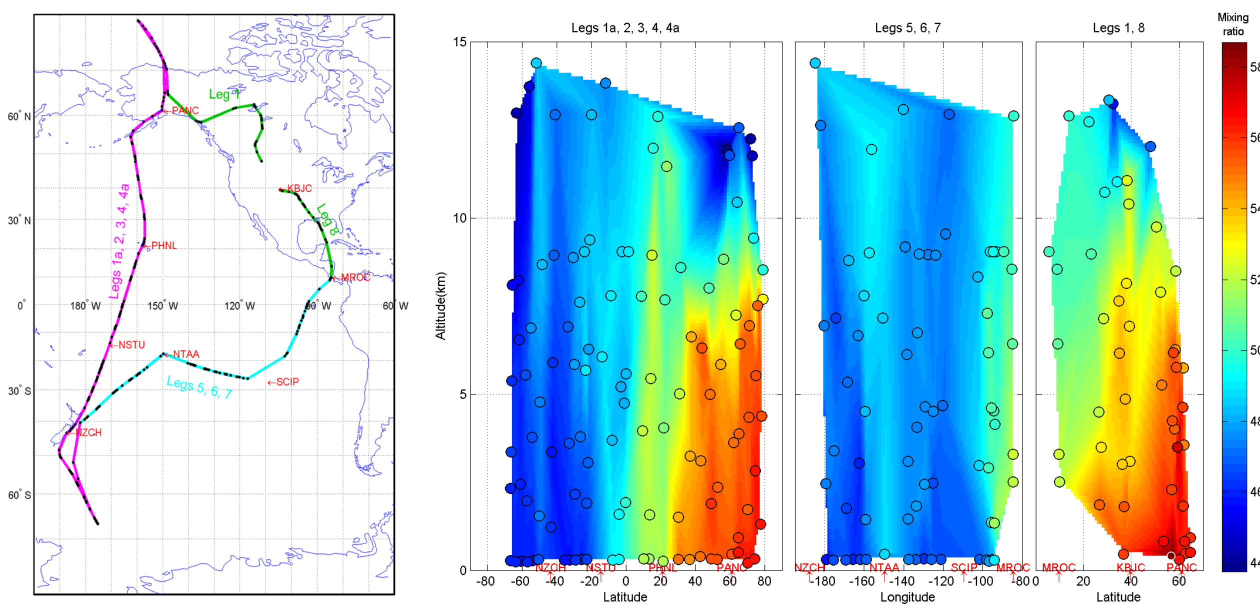

Figure 1. HIPPO January 2009. Left-most panel shows flight track with black dots indicating the 233 flask sampling locations along the 8 flight legs. The sampling began in Billings, Montana and proceeded in a counter-clockwise direction ending in Boulder, Colorado. Black circles in the three right panels indicate the altitude (km) and latitude or longitude for those same samples. The colors within the black circles denote the measured HFC-134a mixing ratio in parts-per-trillion (see colorbar). A surface was fitted to the measurements to produce interpolated values between data points to serve as an aid for the eye in grouping data and should not be misconstrued as indicating atmospheric "features". Airport locations (in red) are PANC Anchorage, AK; PHNL Honolulu, HI; NSTU Pago Pago, AS; NZCH Christchurch, NZ; NTAA Tahiti; SCIP Easter Island; MROC Costa Rica.

Global Trends in SF_6 from the Halocarbon Flask Sampling Network

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Tropospheric mixing ratios of sulfur hexafluoride (SF_6), a very long-lived greenhouse gas, have been increasing steadily over the last few decades. The NOAA Earth System Research Laboratory has maintained programs to monitor SF_6 in the background atmosphere. As part of one such program, air samples have been collected at eight sites throughout the world since 1994 and three additional sites added later. These samples are compared to compressed gas standards prepared gravimetrically at NOAA. The SF_6 calibration scale has recently been updated, resulting in small changes to the NOAA SF_6 scale. Flask data from the Halocarbon sampling network have been updated to reflect these changes. Atmospheric SF_6 data from this program indicate that the atmospheric growth rate of SF_6 has increased in recent years. An analysis of these data and those from other sampling programs, along with reported SF_6 emissions, will be presented in an effort to understand these recent trends.

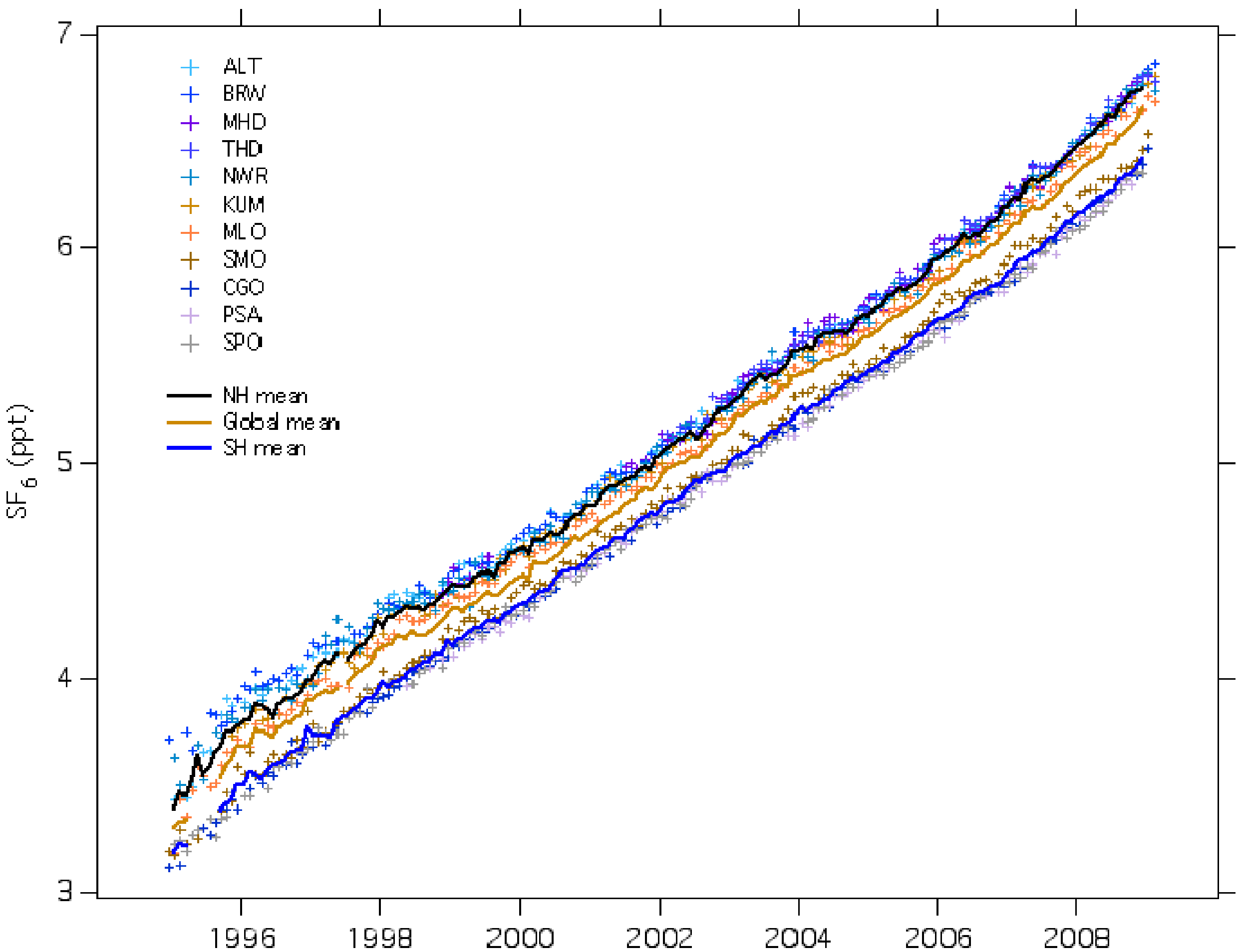

Figure 1. Background atmospheric SF_6 (ppt) from eleven NOAA flask sampling sites.

START-08 and HIPPO: Airborne Projects of the HATS Group in ESRL GMD

J. Elkins[1], F. Moore[2], D. Hurst[2], G. Dutton[2], B. Hall[1], J. Nance[2], S. Montzka[1], B. Miller[2], L. Miller[2], C. Siso[2], D. Mondeel[2], L. Patrick[2], S. Oltmans[1], D. Guenther[2], M. Heller[2], J. Higgs[3], D. Neff[2], C. Sweeney[2] and S. Wolter[2]

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Over the last two years the HATS group has been involved in two high profile projects using the NSF Gulfstream jet operated out of the Rocky Mountain Regional Airport (formerly known as Jeffco). These projects are being managed by the Research Aviation Facility (RAF). The *PANTHER, *UCATS, and *NWAS instrument packages were all involved in measuring gases that play major roles in ozone depletion and or climate forcing (CFC's, HCFC's, HFC's, Hydrocarbons, N_2O, SF_6, CO, CO_2, CH_4, O_3, H_2O, and H_2). The START-08 (Stratosphere-Troposphere Analyses of Regional Transport 2008) project focused on the Stratosphere-Troposphere interface region, from the extra tropics to high latitudes. START-08 samples were collected primarily over North America. The HIAPER Pole-to-Pole Observations of greenhouse gases mission (HIPPO) focuses on global processes such as land-ocean boundary layer interactions with the free troposphere, and inter hemispheric exchange process. HIPPO samples were collected in repeated vertical profiles throughout most of the troposphere from very high northern latitudes to very high southern latitudes. We will present a poster containing a light overview of the instrumentation used and the project goals.

* PANTHER: The PAN and other Trace Hydrohalocarbon ExpeRiment
* UCATS: Unmanned aircraft systems Chromatograph for Atmospheric Trace Species
* NWAS: NOAA Whole Air Sampler

Figure 1. Google earth plots of the NSF Gulf Stream flight tracks for 18 START-08 research flights over North America, and 11 HIPPO research flights that acquired over 60 vertical profiles with near Pole-to-Pole coverage.

Decadal Brightening of Downwelling Shortwave in the Continental U.S.

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Recent studies have reported decreases in downwelling solar irradiance of 2-3 Wm^{-2}/decade at the earth's surface from the 1960s through the early 1990s, and referred to that phenomenon as "global dimming." Our study, as well as others who used worldwide BSRN data, reveal a "brightening" of about the same magnitude from 1992 through the early 2000s, discounting Pinatubo effects. There is disagreement on whether changes in clouds or aerosols caused the observed brightening. To address this problem, we use data from the ARM Central Facility in Oklahoma and ESRL's national SURFRAD network. Seasonal and annual averages were computed in a way that minimized the effects of bad or missing data. A clear-sky identification algorithm was applied to separate the effects of aerosols and clouds. At the ARM site, increases of +3Wm^{-2} for clear-sky and +6 Wm^{-2}/decade for all sky conditions were observed from 1996 through 2007, with the greatest increases in the diffuse component for both. Seasonally, the greatest brightening occurred in the winter and fall, with dimming occurring in spring. These annual and seasonal shortwave trends are anticorrelated with cloud cover. All sites exhibit an increase in global irradiance, with an aggregate average of +7.8 Wm^{-2}/decade (see figure), also with most of the increase in the diffuse. Most of these irradiance increases were accompanied by decreases in cloud cover both in the daytime and night (only one site showed an increase in cloudiness). Model calculations show that an inordinately large aerosol optical depth of 0.2 would be required to increase the clear-sky diffuse by the +3Wm^{-2}/decade that was observed for clear skies at the ARM site. The increase in national average clear-sky diffuse was even greater at +4.5Wm^{-2}/decade. These analyses strongly indicate that changes in cloud cover are largely responsible for the observed brightening over the U.S.

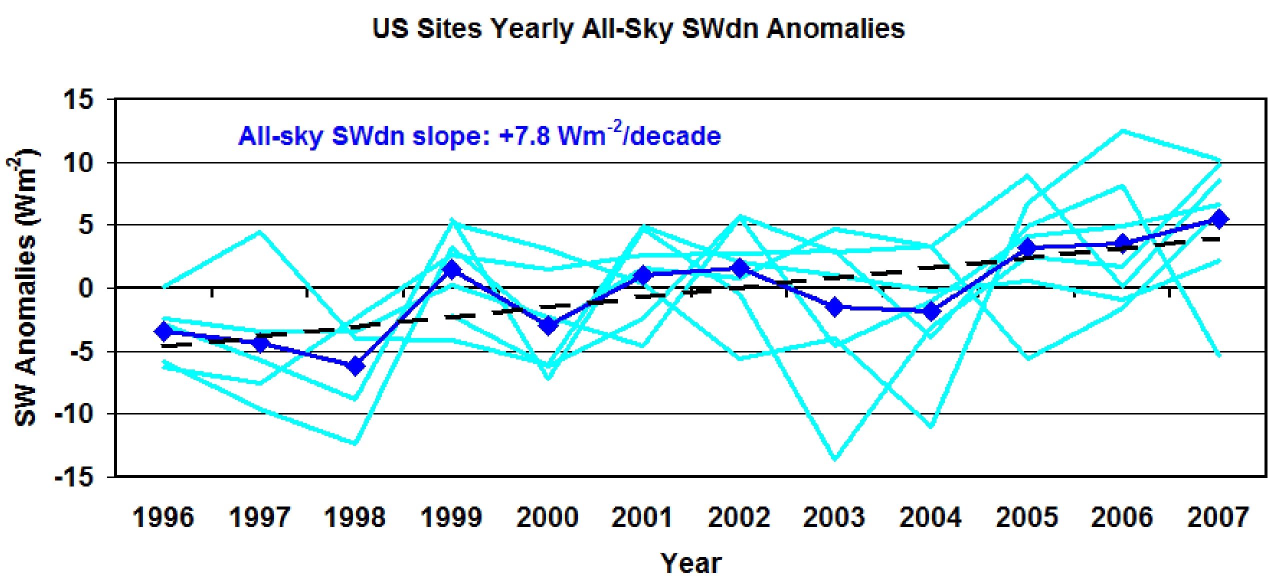

Figure 1. Annual average anomalies of all-sky downwelling solar irradiance for the ARM Central Facility and six SURFRAD stations (light blue). The dark curves represents the aggregate average (dark blue) and corresponding least squares fit (dashed).

Shortwave Spectral Radiative Closure Studies at the ARM Southern Great Plains Climate Research Facility

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The Department of Energy Atmospheric Radiation Measurement (ARM) Program's commitment to collecting spectrally resolved radiometric measurements and coincident atmospheric state measurements at its climate research facilities has enabled extensive radiative closure studies across the electromagnetic spectrum. The concept for radiative closure experiments using spectral measurements and line-by-line radiative transfer model calculations has been successfully used to: 1) validate and improve continuum absorption models and spectral line parameters used in line-by-line models, 2) assess the ability to define the atmospheric state used in the model calculations and 3) assess the quality of the radiation observations themselves. The design of the radiative closure experiment allows all three of these aspects to be simultaneously addressed.

This poster will detail results from recent shortwave radiative closure studies performed between direct-beam transmittances derived from the rotating shadowband spectroradiometer (RSS) irradiance measurements (360–1050 nm) and corresponding calculations performed by the Code for High Resolution Accelerated Radiative Transfer (CHARTS); the spectral line parameters are obtained from the current HITRAN database and the water vapor continuum model MT_CKD utilized. The comparisons are used to evaluate the accuracy and inter-band consistency of water vapor absorption parameters in three adjacent water vapor bands centered at 720, 820, and 940 nm. The goal of this effort is to improve the accuracy of these parameters, which would in turn improve global climate model calculations.

A parallel analysis has focused on the assessment of measured/retrieved aerosol properties in cloud-free conditions using both RSS transmittances and shortwave spectroradiometer (SWS) zenith radiance measurements (350-2170 nm). Measurements from an independent radiometer are used to derive aerosol optical depth; aerosol single scattering albedo and asymmetry parameters are derived from *in situ* measurements. A range of aerosol loading, surface conditions, and solar positions are included in the study. Initial results show approximate agreement between the RSS-derived transmittances and those from the CHARTS calculations.

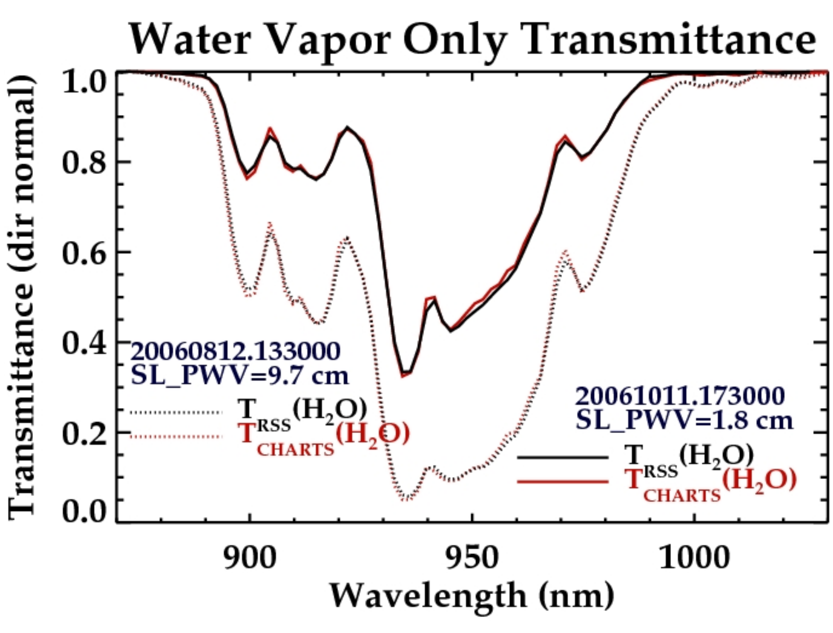

Figure 1. Comparison of RSS-derived transmittance (black) and LBLRTM/CHARTS-calculated transmittance (red) for 940-nm water vapor band for two different water vapor loadings.

Aerosol Climatology for the ARM Climate Research Facility In North-Central Oklahoma: 1992 - 2008

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Aerosol optical depth (AOD) has been measured at the Atmospheric Radiation Measurement (ARM) central facility near Lamont, Oklahoma, since the fall of 1992. Most of the data presented are from the multi-filter rotating shadowband radiometer (MFRSR), however, as many as four simultaneous AOD measurements have been made routinely at the site including sun-pointing sunradiometry. Comparisons are shown. The early part of this 16-year record had a disturbed stratosphere with residual Mt. Pinatubo aerosols, followed by the cleanest stratosphere in decades. As such the last 13 years of the record reflect changes that have occurred predominantly in the troposphere. The field calibration technique is briefly described and compared to Langley calibrations from Mauna Loa Observatory. A modified cloud-screening technique is introduced that increases the number of daily-averaged AODs retrieved annually to about 250 days compared to 175 days when a more conservative method was employed in earlier studies. AODs are calculated when the air mass is less than six, i.e., when the sun's elevation is greater than 9°. The more inclusive cloud-screen and the use of most of the daylight hours yield a data set that can be used to more faithfully represent the true aerosol climate for a site. The diurnal aerosol cycle is examined seasonally to assess the effects of aerosol climatology measurements based on less frequent sampling such as those from satellites.

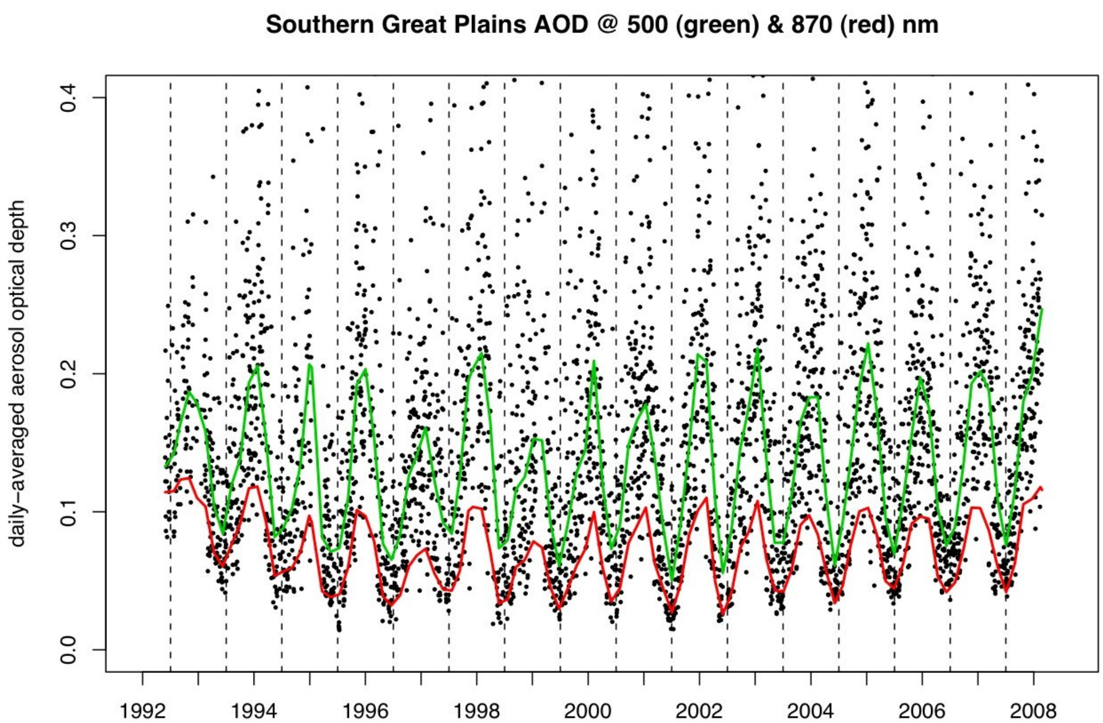

Figure 1. Black points are over 4000 daily averages of AOD at 500 nm. Green and red lines are lowess estimates of the seasonal behavior of the AODs at 500 and 870 nm, respectively.

The NOAA Earth System Research Laboratory Airborne Aerosol Observatory: Climatology and Seasonal Variation of Aerosol Properties Over Central Illinois

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In June of 2006, ESRL began conducting regular (2-3 times per week) light aircraft measurements over central Illinois. The program is the Airborne Aerosol Observatory (AAO), and the platform is a Cessna T206H aircraft. The primary objective of this program is to obtain a climatology of aerosol properties aloft for evaluating aerosol radiative forcing and testing chemical transport models. Through the end of March 2009 (~33 months), 334 research flights have been conducted, most of these over the Bondville surface station. Statistical distributions and climatologies of aerosol properties have been compiled for the set of AAO research flights. While insufficient to determine long-term trends, the nearly three years of data permit us to begin to understand seasonal variation of the aerosols over central Illinois. Low altitude fly-bys of the Bondville station show that surface measurements of aerosol extinction are representative of aerosols in the lowest km of the column. Although individual profiles can be quite variable, the climatological profile of single-scattering albedo shows very little variation in the vertical. Comparisons of AAO aerosol data have been made with measurements collected on another Cessna 206 aircraft flying a similar aerosol package in profiles over Oklahoma. Comparisons of AAO measurements with Aeronet sunphotometer and CALIPSO satellite-borne lidar data will also be discussed.

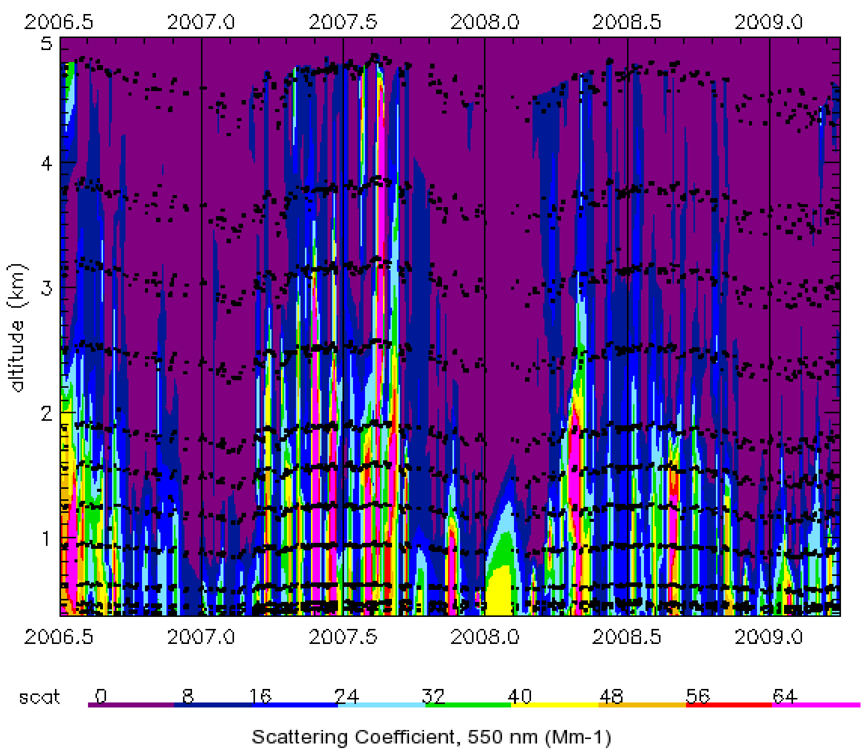

Figure 1. Contour plot of dry aerosol light scattering coefficient (550 nm) vs. time measured by the AAO over central Illinois. Black dots represent individual level flight segments. Seasonal variation in the scattering data is evident, with larger scattering coefficients extending to greater heights above the surface in the spring through fall time frame. Elevated aerosol layers are relatively rare during the winter months. Boundary layer aerosols and aerosol layers aloft tend to last over synoptic (i.e., days to weeks) time scales, consistent with build up and removal by meteorological events.

The NOAA ESRL Collaborative Global Surface Aerosol Monitoring Network

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The NOAA Earth System Research Laboratory maintains five Baseline Observatories to monitor the atmospheric background levels of trace gases and aerosols. Measurements at these remote sites permit us to determine to what extent the global backgrounds are changing over time. Since aerosols are perturbed near the sources, these Observatories are in prime locations to assess baseline changes to the atmospheric aerosol. With the recent interest in anthropogenic aerosol radiative forcing and its effects on climate forcing, ESRL has expanded its network of surface measurement sites to locations that are at times influenced significantly by anthropogenic emissions. This long-term strategy should permit the determination of how much of the forcing at these locations is caused by human activities. In order to reduce the uncertainties associated with extrapolating relatively few discrete observations up to regional or global scales, many more stations in different climatological regions are needed. Unfortunately, there is no way ESRL's budget can fully fund such an endeavor. The primary way we have been able to expand the network to include another major anthropogenic aerosol source region (southeast Asia), the region considered the bellwether of global climate change (the Arctic), and other perturbed areas is to foster collaborations between NOAA ESRL and interested organizations in the U.S. and around the world. The collaborations we have developed present advantages for both parties, and the data collected are directly comparable with that from other stations in the network. This poster describes the essence of these collaborations.

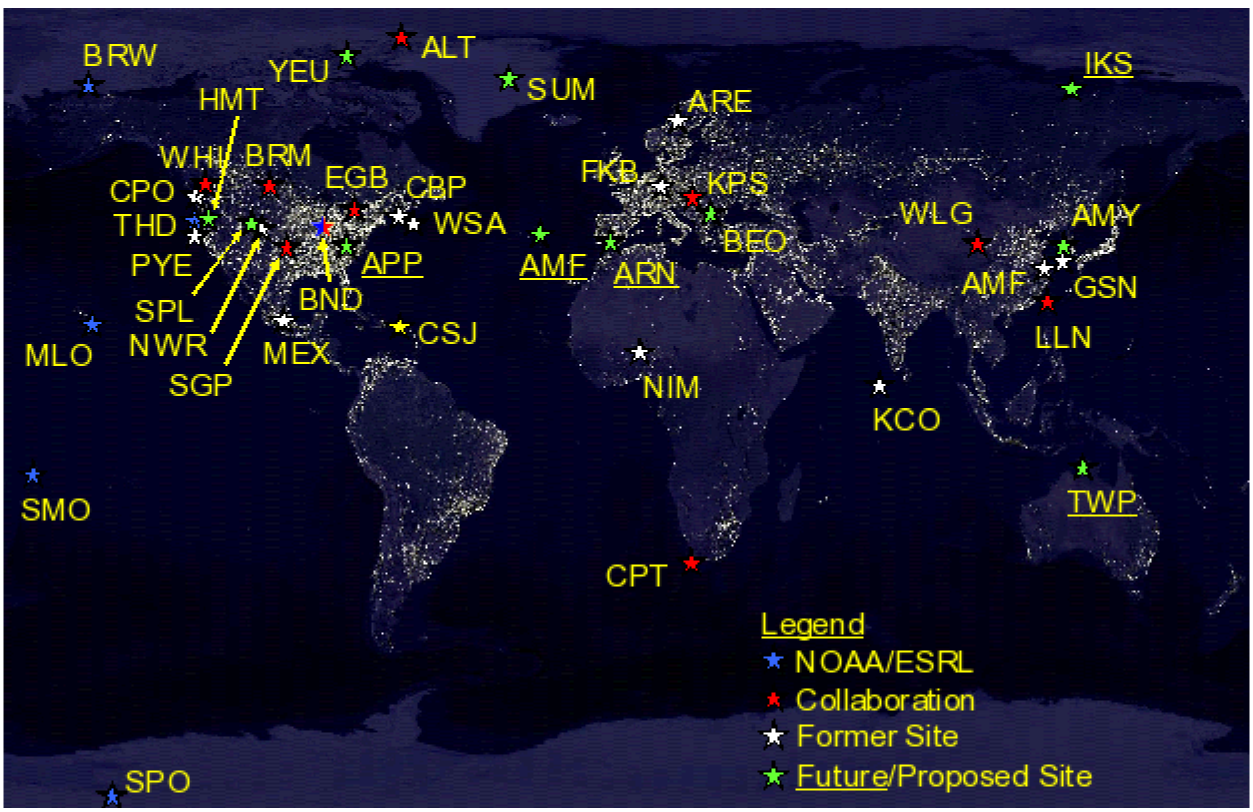

Figure 1. The NOAA ESRL Collaborative Global Surface Aerosol Monitoring Network.

Measurements of Sub-Micron Particles Using an Ultra-High Sensitivity Aerosol Spectrometer (UHSAS) from the Mauna Loa Observatory During HAVAIKI, October and November, 2009

D.W. Toohey[1], D.C. Noone[2], B. Gandrud[3] and J.E. Barnes[4]

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During October 2009 an Ultra-High Sensitivity Aerosol Spectrometer (UHSAS, Droplet Measurement Technologies, Boulder, CO) sampled sub-micron aerosols (55 nm < D < 1000 nm) with 10-second resolution at the NOAA Mauna Loa Observatory in support of the goals of the Hawaii Vapor Isotope Knowledge Experiment (HAVAIKI). HAVAIKI was a focused campaign designed to test the responses of three *in situ* water vapor isotope instruments that were under development and potentially close to market. Following this campaign, the UHSAS remained at the Observatory for the month of November to examine correlations between sulfur dioxide and particulate matter (PM) as a demonstration for closure in the sulfate/PM budget during periods of upslope conditions when volcanic fog ("vog") prevailed at the station. These high-resolution aerosol measurements were designed to provide an independent 'axis' for interpretations of air-mass origins for interpretations of variations in isotopes of water vapor, as well as a means to test the performance of the UHSAS under conditions varying from sampling of dry, free-tropospheric air to recently lofted, and relatively wet, boundary layer air. This poster will present an overview of the measurements to illustrate the value of high-resolution aerosol measurements for interpretations of water vapor isotopes, and preliminary results during particle nucleation events that are consistent with the formation of sulfate aerosols by rapid oxidation of sulfur dioxide in sunlight. An example of observations in a particle nucleation event is shown in Figure 1.

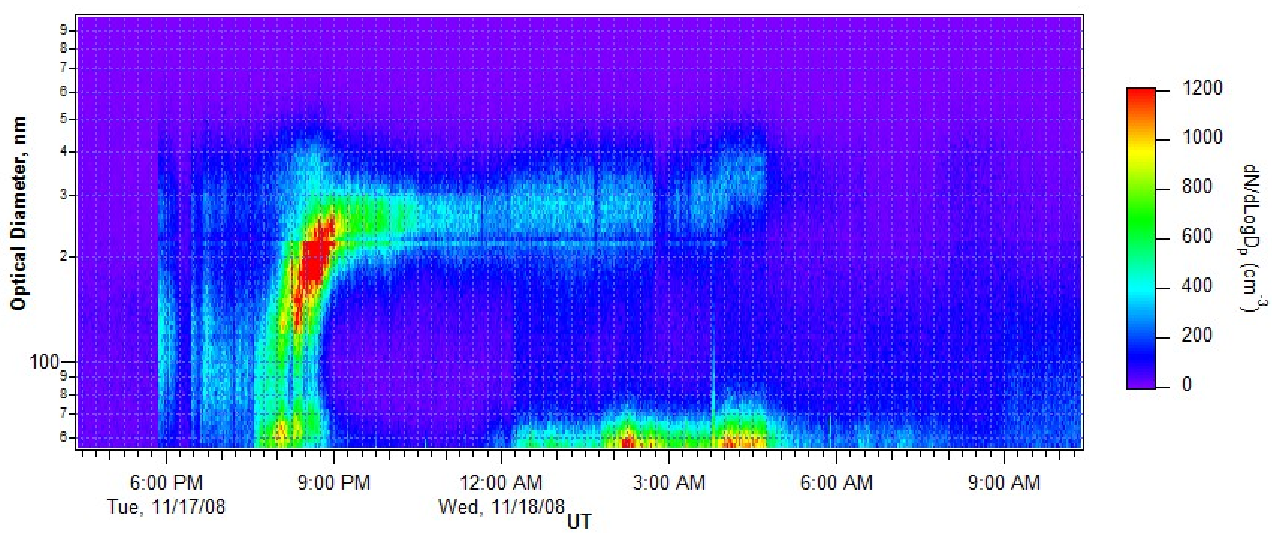

Figure 1. Observations of sub-micron particles on November 17, 2009 from the Mauna Loa Observatory.

Synoptic Transport of Anthropogenic BC to the Arctic

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Synoptic transport of black carbon (BC) from different source regions at the temperate latitudes to the Arctic is explored. Major source regions such as Eurasia (Europe and Former Soviet Union (FSU)), North America and China impact the Arctic during the Arctic haze period as the pollution is transported northward. Figures 1a and 1b show BC emissions compiled from 1990 to 2005 using Cooke et al., 1999's methodology based on United Nations fuel consumption dataset. Emissions from FSU declined in early 90s due to the collapse of Soviet Union. However, since 1998, BC emissions are on the rise in all regions. Here we address the question: are BC emissions or atmospheric transport governing factors controlling BC concentrations in the Arctic? Figure 1c shows a time series of equivalent black carbon (EBC) from *in-situ* measurements at four sites situated in different regions of the Arctic. The sites showed strong synoptic variability in the concentration time series. Among the three coastal sites, Barrow (71.3°N, 156.6°W) is situated on the northern tip of Alaska, Alert (82.3°N, 62.5°W) is in the high Canadian Arctic, Ny Alesund (78.5°N, 11.5°W) is on the Svalbard archipelago north of mainland Europe, and Summit is located on the high plateau of Greenland at 3000 m aMSL (72.6°N, 38.3°W). Interannual variation in the EBC concentrations, from 2002 to 2007, is very similar at these sites in spite of their geographical locations. This suggests that the interannual variation in the synoptic transport to these sites is similar. We used an atmospheric transport model (NIES, National Institute for Environmental Studies) to look at the relative impact of different source regions on these four Arctic sites. The decay of BC is approximated as exponential decay with e-folding time of 10 days. The first scenario, when BC emissions were kept constant while varying the meteorology, revealed the inter-annual variability in EBC due to atmospheric transport at all sites. BC emissions and transport were variable in the second scenario for 27 years, which provided trends in EBC at all sites. The relative contribution from different source regions at Alert indicated a decrease (~30%) in the impact of Eurasian sources and increase (~50%) in North America sources. Simulation results for the other sites will also be discussed.

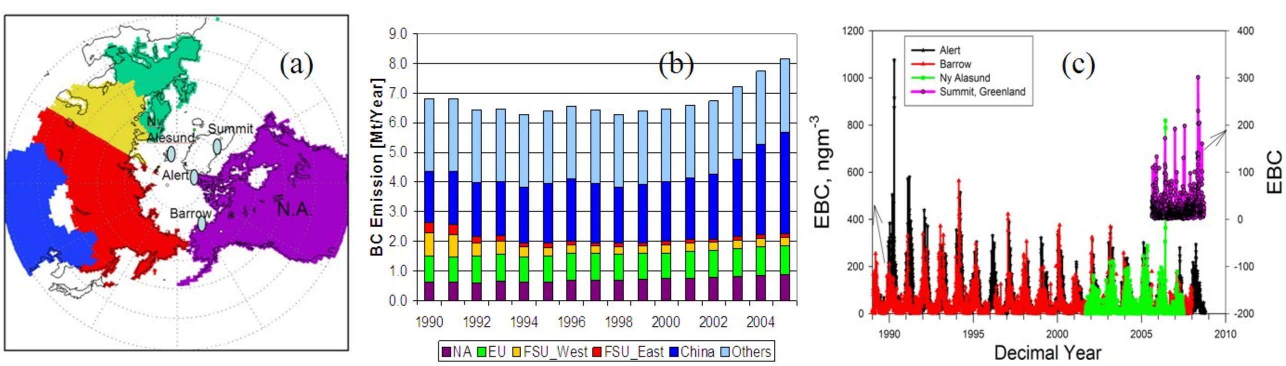

Figure 1. Masks were created to estimate BC emissions inventory in Megatonnes/yr for different source regions (a,b), *in-situ* measurements of EBC at four sites (c).

Spatial and Temporal Variations of Aerosol Optical and Chemical Properties at Five Canadian Sites

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Aerosol optical properties are related to its various chemical components; black carbon absorbs radiation while sulfate and organic carbon are efficient light scatterers. Spatial and temporal variations of the optical and chemical properties are presented at five different sites across Canada that are influenced by emissions from regional sources superimposed on continental background aerosols for 2005-2007: (1) Alert, Nunavut at the northern tip of Ellesmere Island in the high Arctic (influence by “Arctic haze”); (2) BERMSTT, Saskatchewan in the southern edge of the Canadian boreal forest (summer influence by forest fires, biogenic sources); (3) Fraserdale, a forested site in Ontario and located in the southern perimeter of the Hudson Bay Lowlands (summer influence by forest fires, biogenic, anthropogenic); (4) Egbert, Ontario in the rural region located about 80 km north of Toronto (influence by anthropogenic and biogenic - higher concentrations when winds from south but clean air-masses when winds from north); and (5) Whistler, British Columbia at the altitude of 2,180 m MSL in the Pacific Ranges of the Coast Mountains (regional sources and trans-pacific transport of Asian source influence in the spring). The median (mean) aerosol light extinction are 6.2 (7.3) Mm^{-1} at Alert, 7.1 (10.4) Mm^{-1} at Whistler, 7.1 (15.4) Mm^{-1} at BERMSTT, 7.5 (14.2) Mm^{-1} at Fraserdale and 8.5 (17.7) Mm^{-1} at Egbert, respectively. Mass scattering efficiencies for all data are in the range 4.4 to 7.1 m^2g^{-1} at ambient relative humidity. Influence of forest fire increased MSE to 21 m^2g^{-1} as shown in data at BERMSTT site most likely due to larger particle sizes released by fires.

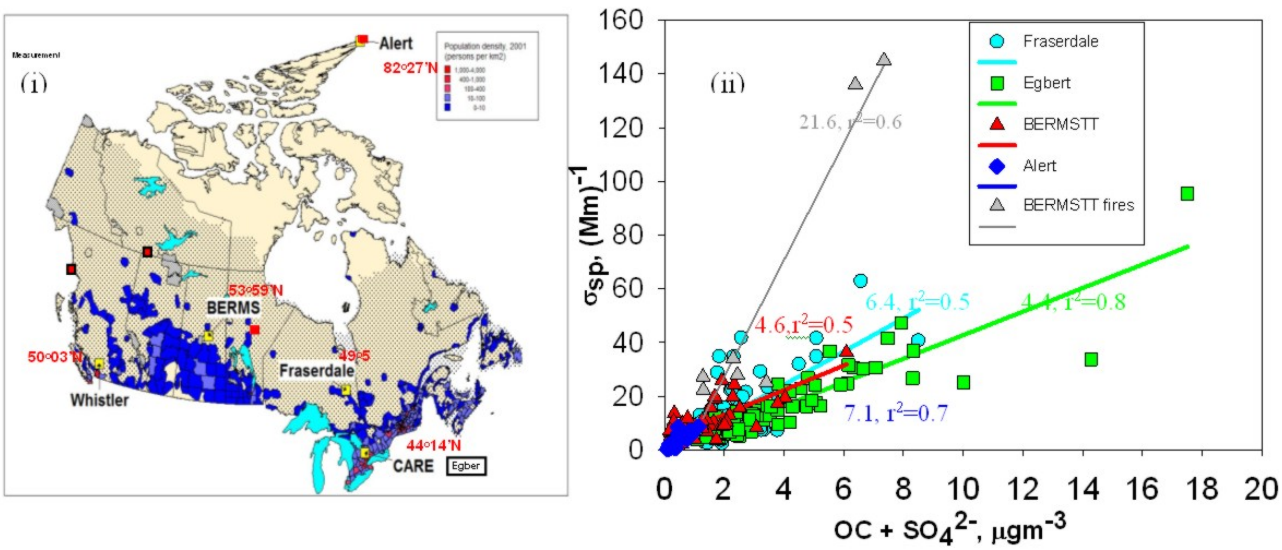

Figure 1. (i) Map showing 5 Canadian Aerosol Baseline Measurement sites, (ii) Aerosol light scattering at 550 nm & at ambient R.H. as a function of organic carbon derived from TOT thermal technique and sulfate from weekly integrated samples at 5 Canadian sites from 2005-2007.

Using a Camera Lidar and Nephelometer for Aerosol Profiling

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A bistatic lidar configuration of a wide-angle camera (100 degrees) and vertically pointed laser was used to profile aerosols at a coastal site. The site, on the eastern tip of the Big Island of Hawaii, is influenced by both marine boundary layer aerosols and breaking waves. Two nephelometers were located at 7 and 25 meters above sea level to compare directly with the CLidar (camera lidar). The high altitude resolution of the CLidar (0.5 meter) allowed a direct measurement of the Extinction/Side-Scatter ratio to be measured. At 7 meters, changes in aerosol were tracked quite well by the CLidar. At 25 meters the aerosol was fairly constant and a useful comparison could only be made on average values. The CLidar results showed a steep gradient (decreasing with altitude) in the aerosol extinction from 7 meters to about 35 meters. The gradient continued to 200 meters at a lower value. This result was useful in characterizing the environment for the *in-situ* aerosol sampling. Two aerosol phase functions were used to convert the single-angle CLidar scatter to extinction. One was a NASA/Aeronet-derived function representing the marine boundary layer from a Lanai, Hawaii coastal site. The other phase function was measured by a polar nephelometer on Oahu, Hawaii and represented breaking waves. The measured function gave the best fit to the nephelometer data. The total aerosol optical depth calculated with the Aeronet phase function was 0.068, similar to the Lanai yearly average of 0.078 at 500 nm.

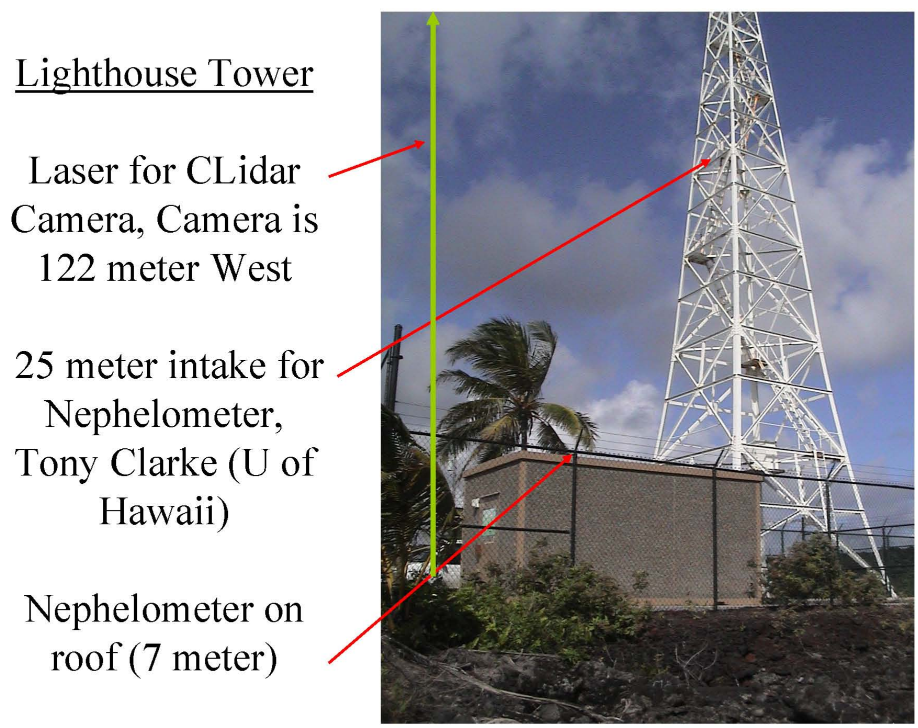

Figure 1. The Cape Kumukahi marine boundary-layer flask sampling site on the eastern tip of the Big Island of Hawaii. The measurements were made about 400-500 meters from breaking waves on the coast.

Aerosol Single Scattering Albedo from Direct-to-Diffuse UV Solar Irradiance at the Table Mountain NEUBrew Site

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Direct and diffuse UV solar irradiance measurements are used to retrieve UV aerosol single scattering albedo during cloud-free periods. The direct-to-diffuse ratio is an indicator of atmospheric conditions and can provide information on aerosol loading, changing surface albedo, and cloud conditions. Six NOAA Environmental Protection Agency Brewer spectrophotometer (NEUBrew) sites are located across the continental U.S. in Boulder, CO, Bondville, IL, Fort Peck, MT, Houston, TX, Mountain Research Station, CO, and Raleigh, NC. Each site has a UV Multi-Filter rotating shadow-band radiometer (UV-MFRSR) measuring direct and diffuse solar irradiance in seven 2-nm wide bands, i.e. 300, 305, 311, 317, 325, and 368 nm. The NEUBrew site located near Boulder, CO has the advantage of having a collocated UV-Rotating Shadowband Spectrograph (UV-RSS) measuring diffuse and direct solar irradiance from 290 – 400 nm, up- and down-welling UV broadband radiometers for surface albedo measurements and is in proximity to a AERONET site. Radiative transfer model calculations (TUV) combined with the direct-to-diffuse solar irradiance (DDR) from the UV-Rotating Shadowband Spectrograph (UV-RSS) and the UV-MFRSR are used to retrieve aerosol single scattering albedo (SSA) under a variety of atmospheric conditions. For the radiative transfer calculations, total ozone measurements are obtained from a collocated Brewer spectrophotometer that is part of the NEUBrew Network.

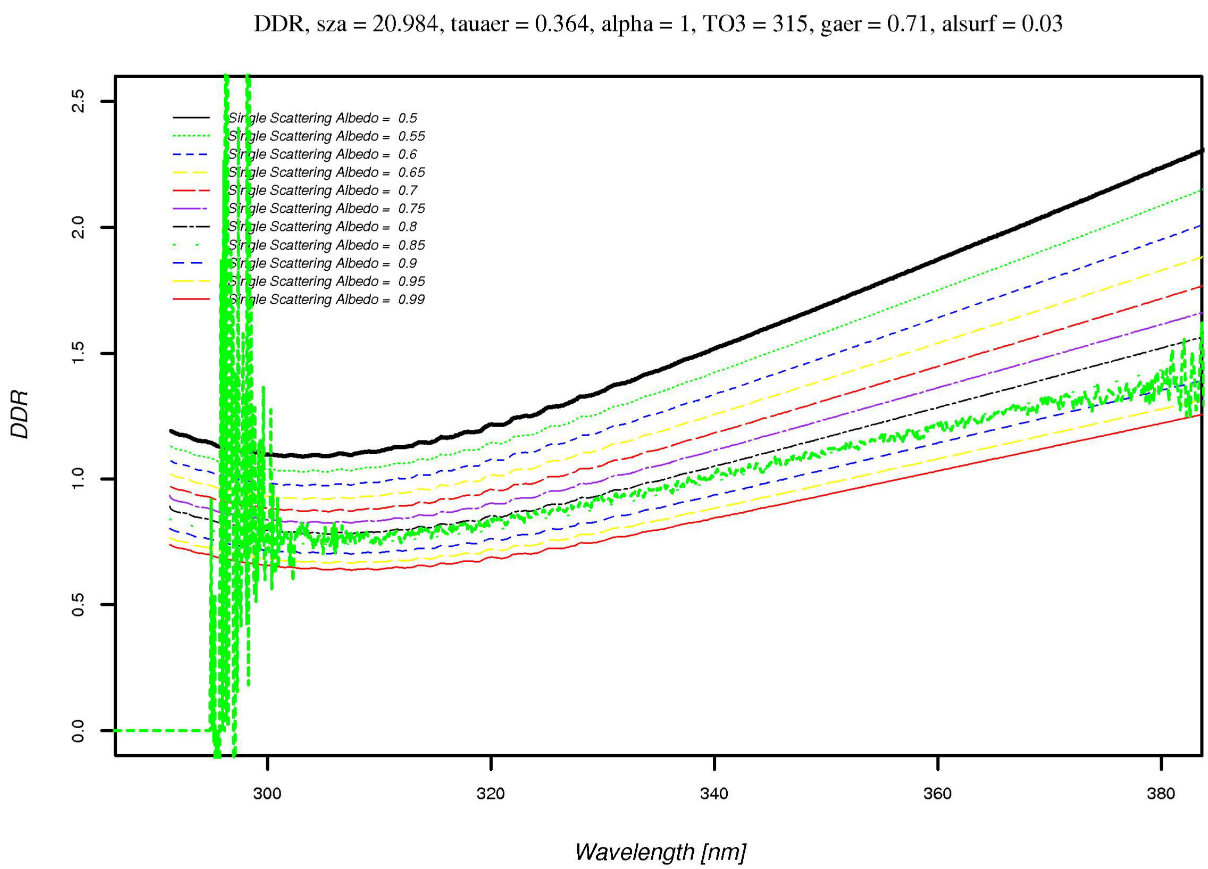

Figure 1. Direct-to-diffuse solar irradiance (DDR) from the UV-Rotating Shadowband spectrograph at a solar zenith angle of 21° (solid green) compared with TUV radiative transfer calculations of DDR as a function of aerosol single scattering albedo using measured input properties for other aerosol properties and surface albedo.

Micro-Pulse Lidar Network (MPLNET) Status and Lidar Observations from the NOAA ESRL Trinidad Head Observatory Site

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The Mirco-Pulse Lidar Network (MPLNET) comprises over 16 sites around the globe where vertical profiles of visible wavelength atmospheric backscatter measurements are recorded continuously over multi-year periods of time. These results contribute to climate change studies and provide ground validation for satellite sensors in the Earth Observing System (EOS) and related modeling efforts. MPLNET is a federated network, and is composed of NASA sites, and others run by partner research groups from around the world. NOAA ESRL baseline observatories contribute two lidar sites to the network: Trinidad Head, California (operated by Humboldt State University) and the South Pole Atmospheric Research Observatory. The Trinidad Head lidar has been in operation since spring 2005, and has collected over 1.5 million profiles of atmospheric backscatter at mid-visible wavelength of 523 nm. The coastal location of the Trinidad Head site is impacted by a variety of aerosol types including marine, intercontinental transport over the Pacific, and other sources. Interpretations of column measurements from satellites and ground sensors, as well *in-situ* measurements, are enhanced significantly when the vertical distribution of aerosol matter is known. Example cases of MPLNET data products will be presented illustrating some of the new web-based user-interface tools to display and present such data. This will include preliminary analysis of inter-continental transport of aerosol layers observed at the Trinidad Head site, with comparisons to satellite and surface observations of these same events.

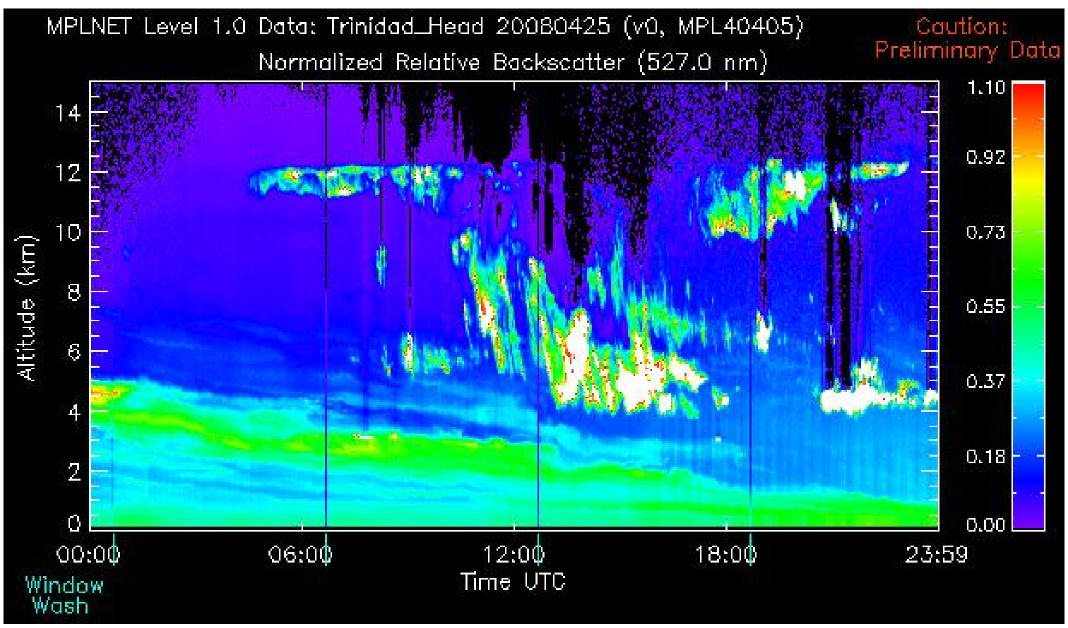

Figure 1. MPLNET normalized relative backscatter image for the Trinidad Head (California) lidar on April 25, 2008. On this day, the lidar reveals multi-layer clouds and a 4 km (at 00:00 UTC) layer that descends towards the surface as the day progresses. This layer is attributed to smoke transported across the Pacific from Russian wildfires in late April 2008.

Comparison of Barrow, Alaska and Tiksi, Russia Climate Variability Using Historical Meteorological Records

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A digital archive of the historical Tiksi meteorological station data (1936 to present) has recently been created for air surface temperature, surface pressure, wind velocity, and cloudiness. A detailed analysis of the Tiksi data has been performed showing the influences of synoptic systems and cloudiness on temperature trends and shore fast ice cycles (presented as a companion paper in this session). In this study, the identical statistical methods are applied to the Barrow, Alaska meteorological data sets.

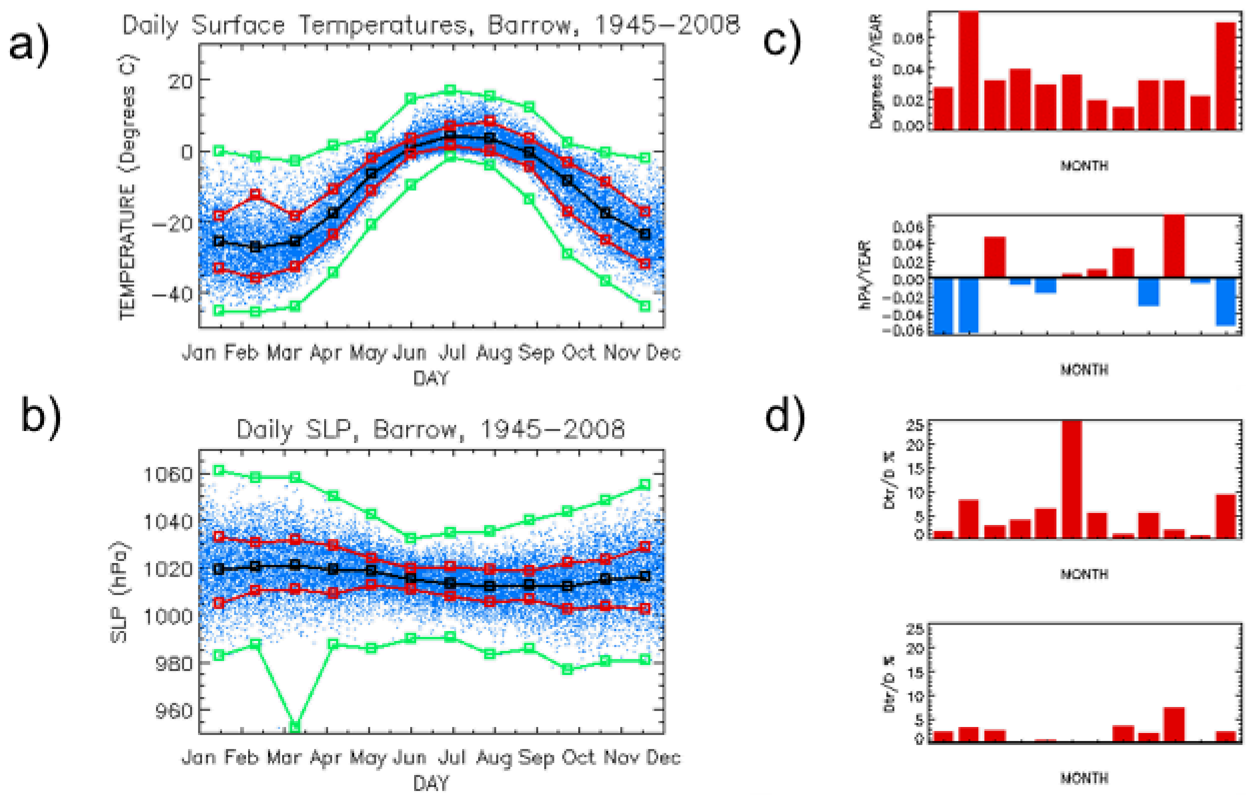

Figure 1. a) Time series of surface air temperature observations: daily values - blue dots, monthly means - black, extreme values from daily observations - green, extreme values from monthly means - red. b) the same, but for sea level pressure c) Linear trends found in the time series of monthly means of surface air temperature (top) and sea level pressure (bottom) for Barrow, 1945-2008 d) Coefficient of determination for the time series of surface air temperature (top) and sea level pressure (bottom) monthly means for Barrow, 1945-2008.

The International Arctic Systems for Observing the Atmosphere - Synergistic Potentials with the NOAA Baseline Observatories

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The NOAA Global Monitoring Division operates 5 Baseline Observatories roughly along a longitude line between Barrow, Alaska and the South Pole, Antarctica. These are all NOAA staffed facilities with observational and science programs focused on the study of atmospheric gases, aerosol particles, solar radiation, ozone depletion and baseline air quality. The International Arctic Systems for Observing the Atmosphere (IASOA) program has similar objectives with the focus on a ring of Observatories in the Arctic region. This program has similar objectives but different requirements as it integrates the activities of facilities in the 8 Arctic nations to achieve a high level of coordinated atmospheric observational capabilities for climate studies. A primary focus of the program is WMO endorsed programs such as Baseline Surface Radiation Networks (BSRN), Global Atmosphere Watch (GAW) and Arctic Monitoring and Assessment Program (AMAP). Barrow, Alaska is a key site that links the two Observatory systems. These two Observatory Systems provide tremendous potential for global scale monitoring and evaluation of climate changes.

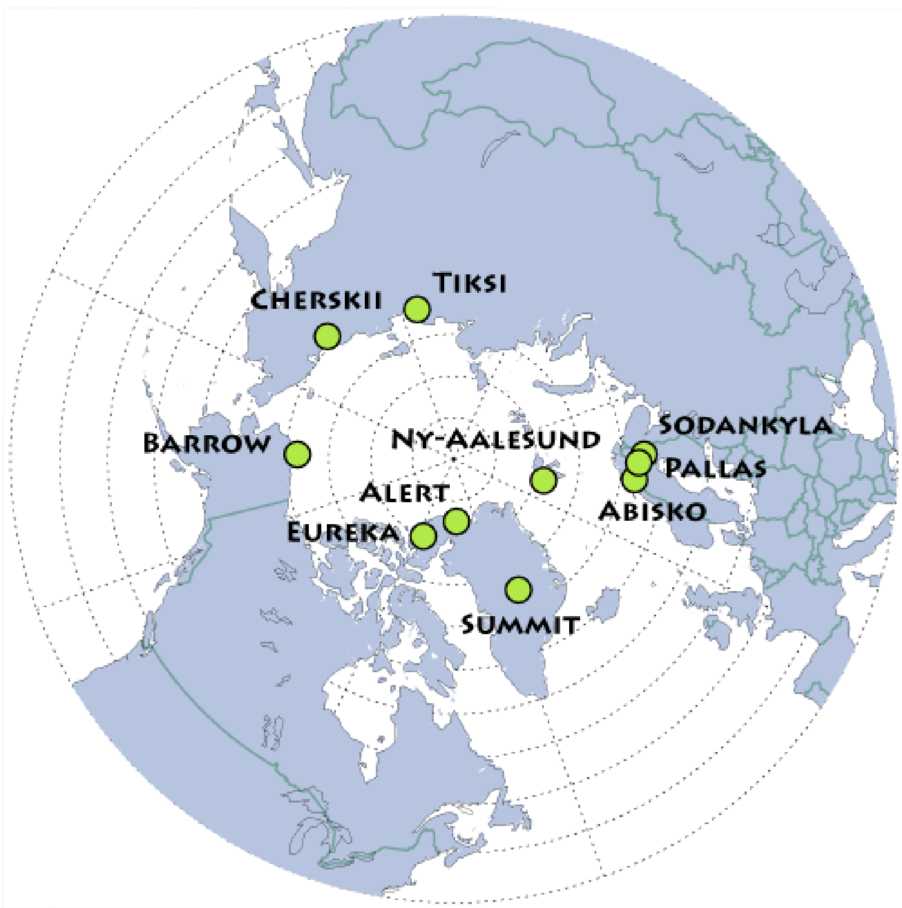

Figure 1. Member Observatories of the International Arctic Systems for Observing the Atmosphere.

A Real Time Display of Meteorological Parameters From the NOAA ESRL Baseline Observatories

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NOAA ESRL maintains a network of 5 baseline observatories around the world with the mission to acquire, evaluate, and make available, accurate, long-term, continuous records of atmospheric gases, aerosol particles, and solar radiation which affect climate, the ozone layer, and baseline air quality, in temporal and spatial scales that allow causes of change to be understood. Basic to all measurements made at the observatories is meteorologic data. The 5 observatories measure wind speed, wind direction, temperature, pressure, and humidity. The poster presented here is a first generation display that shows the most commonly asked for met data by the general public. This includes station identity, temperature, wind speed and wind chill. A programmable LED display is fed a real time data stream from a central computer with data provided by the 5 observatories. The program controlling the LED sign can be modified to allow for the display of any of the available real time data from each site. Mixing ratios of gases, solar radiation data, and aerosol parameters can all be displayed as requested.

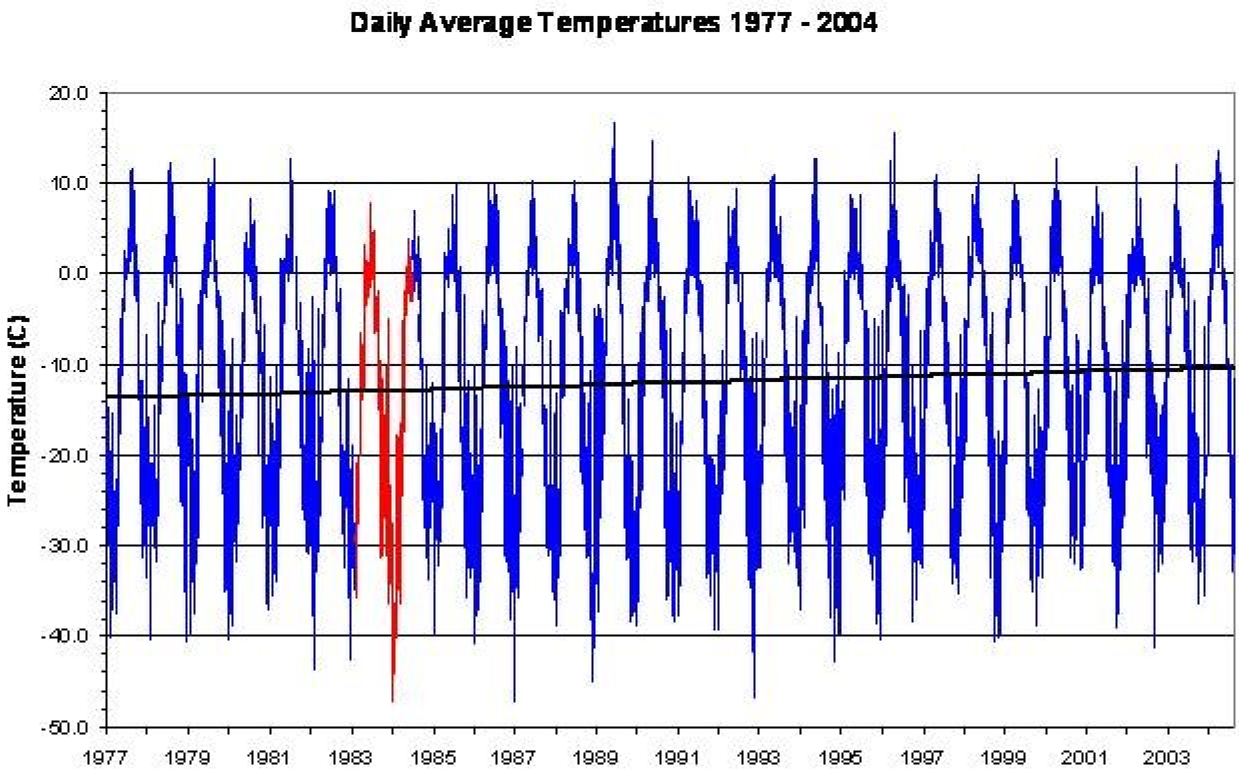

Figure 1. Temperature data from the NOAA ESRL Barrow Baseline Observatory showing a warming trend of .1C over the last 25 years. The data in red are suspect due to a bad calibration.

Long-Term Climate Variability in the Area Surrounding Tiksi, Russia

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A Hydrometeorological Observatory is being developed in Tiksi, Russia as a contribution to the International Polar Year. The Tiksi Observatory will be part of an International Network of Arctic Observatories including Barrow, Alert-Eureka, New-Alesund, Summit, Pallas, and Abisko. Creation of this network with coordinated, intercomparable long-term meteorological observations is motivated by the need to understand the well-documented phenomenon of polar amplified climate warming and the vulnerability of Arctic ecosystem to anthropogenic modifiers. This study investigates the representativeness of the Tiksi location by comparing Tiksi climate data to 2 other stations, Kazachie and Kusur, in the Northern region of Yakutia. These stations are located to the east and south of Tiksi at a distance of about 150 km with continuous data since 1909. For Kusur some additional information is available back to 1820. Tiksi data is available since 1936. A synoptic analysis of meteorological processes at Tiksi, Kusur, and Kazachie has been performed for air temperature, atmospheric surface pressure and total cloudiness for period 1936 - 2007 years on monthly, seasonal and diurnal time scales. The average monthly correlation between Tiksi-Dusur and Tiksi-Kazachie are high, generally > 0.8 (Table 1). This allows linear regression to reconstruct air temperature and surface pressure in Tiksi between 1909 (the start of the Kusur and Kazachie data records) and 1936 (the start of the Tiksi data record). The reconstructed temperature record does not reveal a significant positive trend for the period 1909 - 2007. The month with the strongest positive trend is April (< +0.09 °C/10 years); conversely in some months, negatives trends are as larges as -0.18 °C/10 years.

Station	Month	T	P	N_A		
				1*	2*	3*
Tiksi – Kusur	1	0.89	0.98	0.39	0.42	0.40
	2	0.63	0.82	0.42	0.45	0.48
	3	0.91	0.97	0.69	0.75	0.77
	4	0.84	0.94	0.61	0.67	0.72
	5	0.85	0.92	0.23	0.23	0.22
	6	0.76	0.93	0.49	0..53	0.54
	7	0.72	0.90	0.44	0.51	0..59
	8	0.89	0.92	0.40	0.38	0.42
	9	0.96	0.98	0.43	0.43	0.39
	10	0.95	0.97	0.43	0.48	0.47
	11	0.93	0.96	0.29	0.37	0.37
	12	0.85	0.97	0.40	0.41	0.43
Tiksi – Kazachie	1	0.89	0.92	0.33	0.34	0.38
	2	0.73	0.86	0.44	0.40	0.42
	3	0.95	0.97	0.45	0.49	0.50
	4	0.96	0.97	0.65	0.66	0.67
	5	0.91	0.96	0.39	0.37	0.38
	6	0.72	0.92	0.51	0.52	0.52
	7	0.76	0.90	0.60	0.65	0.65
	8	0.92	0.93	0.53	0.55	0.54
	9	0.95	0.96	0.61	0.61	0.60
	10	0.92	0.97	0.49	0.49	0.48
	11	0.90	0.97	0.32	0.34	0.33
	12	0.88	0.96	0.31	0.31	0.34

Figure 1. Correlation of Tiksi-Kusar and Tiksi-Kazachie Monthly Temperature, Pressure and Cloud Fraction.

ARM Climate Research Facilities on the North Slope of Alaska: An Update on Field Campaigns, Instruments, and Team Changes in 2008, IOPs and Changes in Facilities Planned for 2009

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To provide greater research capability for the global scientific community, the Department of Energy designated the Atmospheric Radiation Measurement Program's scientific infrastructure and data archive as a national user facility: the ARM Climate Research Facility (ACRF). ACRF's role is to provide infrastructure support for climate research to the scientific community. DOE's climate research programs, with focus on clouds and aerosols and their impact on the radiative budget, define the research scope supported by the Facility. Since 1998, the North Slope of Alaska (NSA) ACRF site, with facilities in the towns of Barrow and Atqasuk, has provided data about cloud and radiative processes at high latitudes.

This poster will highlight events at the NSA Facilities in 2008 and upcoming events in 2009. The current International Polar Year 2007-2008 extends through March of 2009, and this past year has seen a number of IPY-related measurement campaigns on the North Slope of Alaska.

The Indirect and Semi-Direct Aerosol Campaign (ISDAC) that occurred in April 2008, included instrumented flights over the Barrow ACRF Facility as well as extensive ground-based measurements there. Results from ISDAC will be presented during scheduled sessions at the 2009 Science Team Meeting. The ISDAC field campaign included coordinated measurements with NASA and NOAA.

The NSA Pyranometer IR Loss Study was extended through the winter of 2008. This study focuses on corrections needed for Pyranometer IR measurements at North Slope Facilities and the effects of ventilation and heating on Pyranometer measurements.

Intensive Operating Periods and field campaign measurements for the coming year include the collection of precipitation to determine the effect of sea ice on Arctic precipitation and cloud radar comparisons and calibration activities.

Upcoming changes to the ACRF North Slope Facilities include addition of several new permanent instruments, leased office and lab space in the recently-opened Barrow Arctic Research Center, and new staff members on the Operations Team in Barrow.

Figure 1. NOAA Barrow GMD Facility (closest), DOE ARM Climate Research Facility (middle), USGS Magnetic Observatory (farthest).

Chemical Precipitation on the Russian Arctic Territory

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Precipitation chemistry remains a major environmental issue in several parts of the world (e.g., Eastern North America, Southeast Asia, and Europe) due to concerns over acid deposition, eutrophication, trace metal deposition, ecosystem health, biogeochemical cycling, and global climate change. For the estimation of the influence of emissions on the Arctic territory there needs to be included regular measurements of chemical precipitation (wet depositions). In Global Atmosphere Watch (GAW) the following compounds are recommended for analysis precipitation samples: pH, conductivity, sulphate, nitrate, chloride, ammonium, sodium, potassium, magnesium and calcium. Data from Tiksi is printed below.

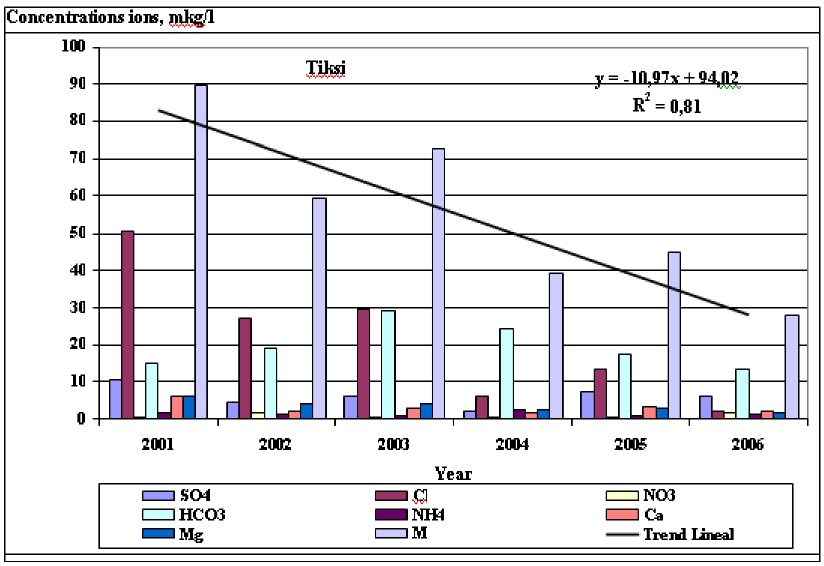

Figure 1. Concentrations main ions in precipitation at the Tiksi Station for 2001-2006 years.

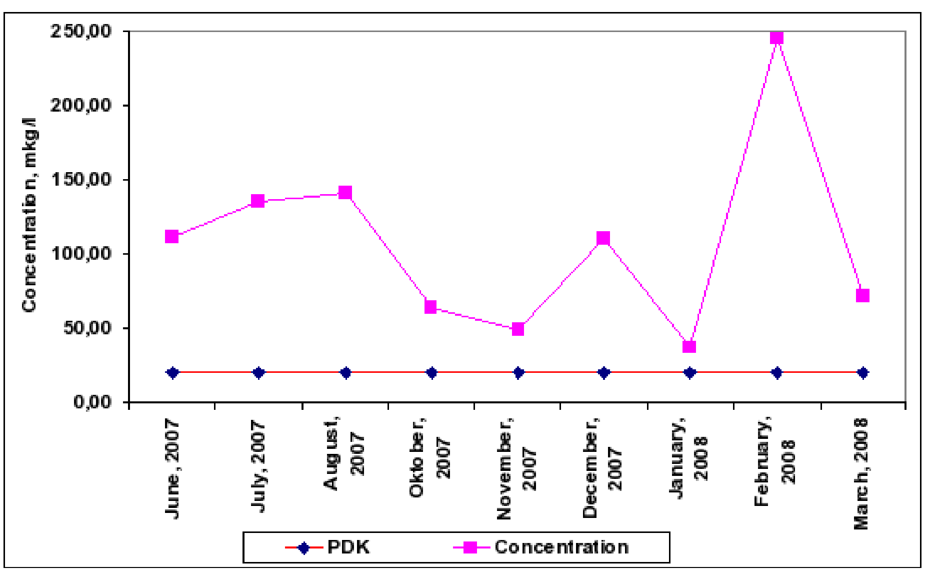

Figure 2. The concentrations of nickel in precipitation, Station NP-35 (IPY), 2007-2008 years.

Detection and Characterization of Systematic Errors in Atmospheric Models

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Modern numerical weather prediction models typically use 3 or 4 dimensional variational assimilation (3D or 4DVAR) to define their initial conditions. In most cases, variational assimilation techniques assume that the distribution of observation and model errors are statistically normal and unbiased. Recent work at ESRL’s Global System Division has detected clear evidence of systematic errors in the analysis and prediction of total atmospheric column precipitable water vapor (TPW) in operational NWP models over the continental U.S. Because of the importance of water vapor in weather and climate processes, the weather forecasting and climate monitoring/prediction communities share a mutual interest in identifying and correcting systematic moisture errors in both observations and predictive models. This presentation describes how these errors were detected and how they appear to propagate with time.

Figures 1 and 2 illustrate the differences between an operational NCEP global model (the GFS presented in the top panel of both figures) that does not assimilate GPS TPW and a synoptic model (NAM or WRF-NMM in the bottom panel of both figures) that does. Of special note is the fact that the NAM uses the GFS to define the initial conditions at the boundary. We note with great interest the existence of a dry bias of the GFS model with respect to GPS during the warm seasons, and how these differences do not significantly change over a 12-h period. In contrast, the NAM does not appear to have a significant seasonal bias in either the analysis or 12-h prediction of TPW, but the standard deviation of the differences grows in 12-h to be almost (but not quite) identical to the GFS.

Because the cause(s) of these errors are not well understood, we propose that this is a fertile area for collaborative research within ESRL.

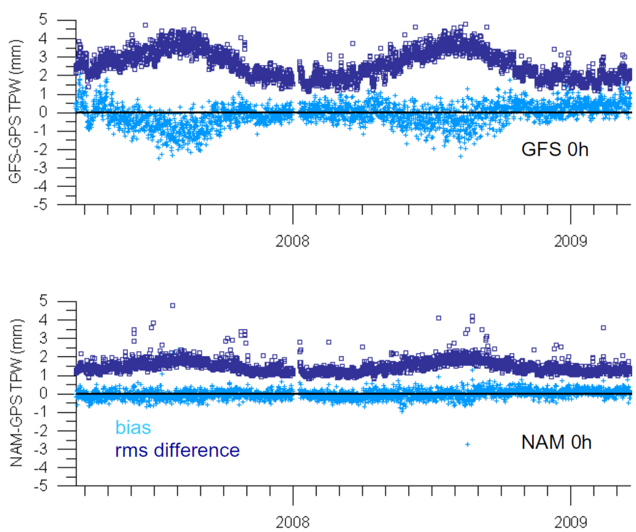

Figure 1. Difference between NWP model analyses & GPS retrievals of TPW valid at 0, 6, 12, & 18 UTC at about 300 sites over CONUS between March 2007 and March 2009. GFS-GPS (top) and NAM-GPS (bottom).

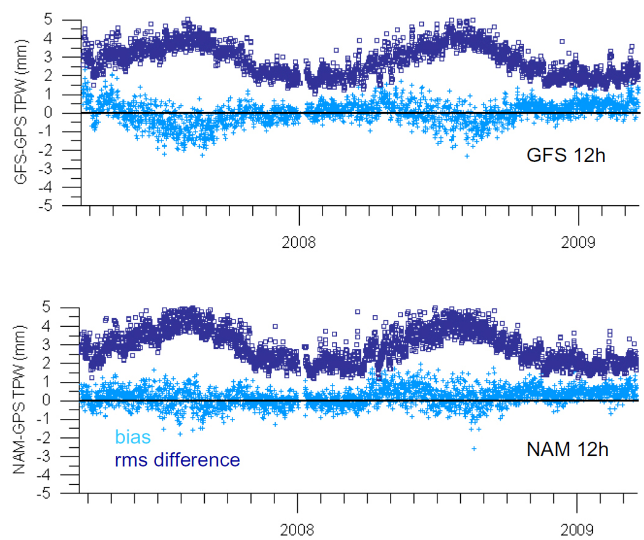

Figure 2. Differences between 12-h model forecasts & GPS retrievals of TPW at the same sites and times evaluated in Figure 1.

Zero Waste: A Practical and Effective Approach to Reducing Human Impacts on Climate

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Recycling began in the United States in the early-1970s due to a growing awareness of population and environmental pressures upon our ecosystems. Since then, curbside recycling programs have expanded and become mainstream, and some communities are accepting compostable materials at curbside. Even though almost 80% of the materials thrown away by Americans are recyclable, our recycling rate is just 28% (EPA). The remaining materials, more than 137 Mt (106 tons) (EPA), are primarily hauled to landfills where organic materials break down in an anaerobic process that produces methane (CH_4). Landfills are a major source of anthropogenic CH_4, a greenhouse gas, contributing to climate change. CH_4 is 72 times more effective at capturing infrared radiation than carbon dioxide (CO_2) over a 20-year period, making it a good target for short-term reductions in climate forcing. Composting organic materials, such as yard trimmings, non-recyclable paper, and food scraps, releases biogenic CO_2 instead of CH_4, reducing our impact on climate. Composting also creates a valuable soil amendment that conserves water, prevents erosion, reduces pesticide use, and stores carbon in soils. The U.S. has the potential to decrease landfill-based methane emissions by 406 Mt CO_2 equivalent per year by 2030 by dramatically reducing our waste stream to the landfill. A new zero waste program in the U.S. "would reduce greenhouse gas emissions the equivalent of closing one-fifth of the existing 417 coal-fired power plants" (Stop Trashing the Climate, Platt, B., et al). Figures 1 and 2 show the Business As Usual scenario and the Zero Waste Approach to disposing of waste in the U.S. By 2030, 90% of domestic waste could be diverted from landfills to recycling and composting, achieving a 7% cut in equivalent CO_2 emissions. The David Skaggs Research Center expanded its recycling program to include composting in October 2008. Since then, we have diverted 70% of our waste from the landfill through composting and recycling. NOAA's Earth System Research Laboratory is at the forefront of climate research and understands how important it is to reduce our impacts on the planet. By adopting a zero waste program, we are seeing how very little effort can make a difference in our greenhouse gas emissions while also conserving resources, protecting ecosystems, and reducing pollution.

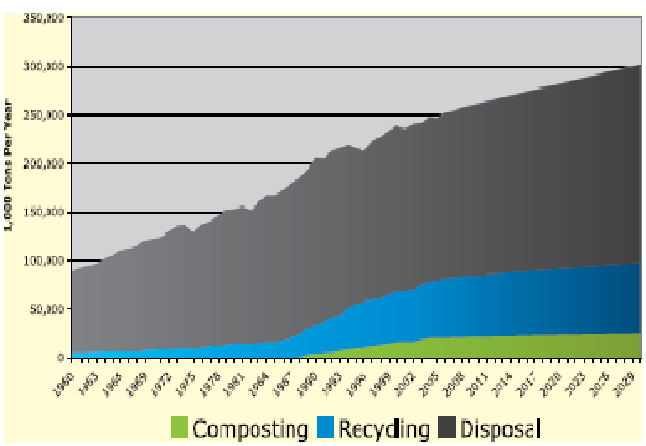

Figure 1. Business As Usual Recycling, Composting, and Disposal.

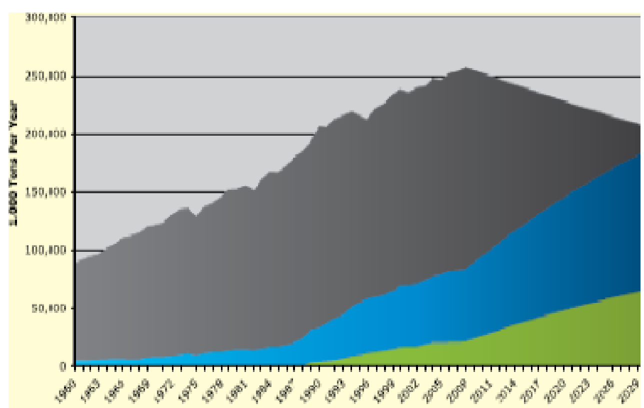

Figure 2. Zero Waste Approach. Source: B. Platt and H. Bhalala from Stop Trashing the Climate.

Wind-Flow Characteristics at the Heights of Modern Wind Turbines from Lidar Measurements

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The nascent wind-energy industry is heavily dependent on meteorological conditions. Locating new wind energy farms is fraught with uncertainty regarding their economic viability. In addition, wind turbines frequently fail sooner than their claimed life expectancy, and it is believed that this may be due to local wind-shear and turbulence levels that exceed those predicted by current theory and models. Almost no routine wind and other meteorological data exist in the 30-300 m layer, the lower portion of which is occupied by wind turbines, except the twice-daily rawinsonde observations. As a result, the accuracy of the numerical and analytical models is unknown or needs to be validated by high-quality measurements. Therefore, a strong requirement exists for new datasets that adequately describe the atmospheric boundary layer structure at the heights of modern and future wind-turbines.

Recently, remote sensing instruments have become a valuable alternative for wind-energy needs, by providing wind and turbulence measurements with sufficient vertical and time resolution.

One such instrument, the High-Resolution Doppler Lidar (HRDL), a scanning system developed at the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL). The HRDL has been used in meteorological applications to study air quality and dynamic processes in the atmospheric boundary layer, including very strong and frequent nocturnal low-level jets over flat terrain in the Great Plains and extreme atmospheric events such as passages of cold fronts. The ability of HRDL to provide accurate measurements of wind and turbulence conditions at multi-megawatt turbine heights above the range of tower measurements makes this instrument a powerful tool for wind-energy related studies. Better knowledge of wind regimes at the turbine heights can significantly reduce the uncertainty in wind resource assessment, electricity production and structural safety of turbine hardware, and thus decrease turbine operational and maintenance costs.

Detailed analysis of HRDL measured wind and turbulence profiles, wind flow statistics over the Great Plains, along with some examples of atmospheric events that can impose critical loads on wind turbines, will be given.

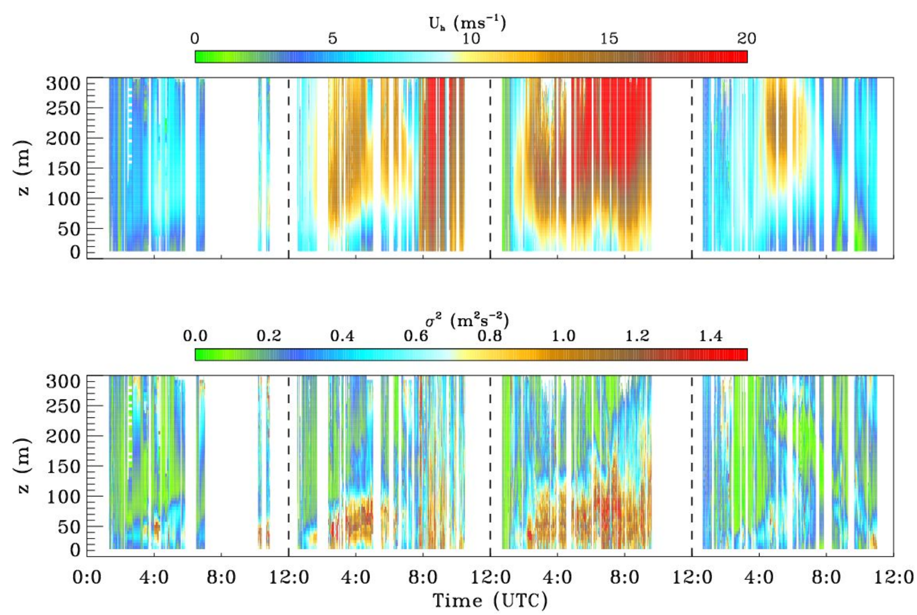

Figure 1. Time-height cross sections of (top) mean horizontal wind and (bottom) variance, calculated from HRDL measurements illustrate significant differences in the magnitude of wind and turbulence for consecutive nights in September 2003.

The Nonhydrostatic Icosahedral Model

J. Lee and A.E. MacDonald

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The Earth System Research Laboratory (ESRL) is developing a new global finite-volume Nonhydrostatic Icosahedral Model, named the NIM, for earth system modeling, and weather and climate prediction. The model uses innovations in model formulation similar to those of the hydrostatic Flow-following Icosahedral Model (FIM) developed by ESRL and now being tested for future use by the National Weather Service as part of their operational global prediction ensemble. Innovations from the FIM used in the NIM include:

- A local coordinate system remapped to a plane for each grid point,
- Grid points in a linear horizontal loop that allow any horizontal point sequence,
- Flux Corrected Transport formulated based on the high-order (3rd Order) Adams-Bashforth scheme to maintain conservative positive definite transport,
- All differentials evaluated as line integrals around the cells,
- Strict conservation of passive tracers to the round-off limit, and
- Computational design to allow for scalability to hundreds of thousands of processors.

The FIM and NIM models use finite-volume techniques pioneered by S. J. Lin of GFDL. The NIM will use the vertically Lagrangian coordinate system developed by Lin. It will use the Earth System Modeling Framework and be part of a modeling system being developed by ESRL, GFDL and AOML. Numerical design goals of the NIM include the development of Piecewise Parabolic third order differencing and Vandermonde polynomials allowing high-order approximations of local variables in the horizontal, and a Lagrangian Riemann Solver for vertical differencing. NIM will have the capability to run globally at kilometer scale resolution, which would allow convective macro-phenomena like the Madden-Julien Oscillation to be explicitly predicted. Other important properties include the high conservation needed for earth system modeling of chemistry and aerosols.

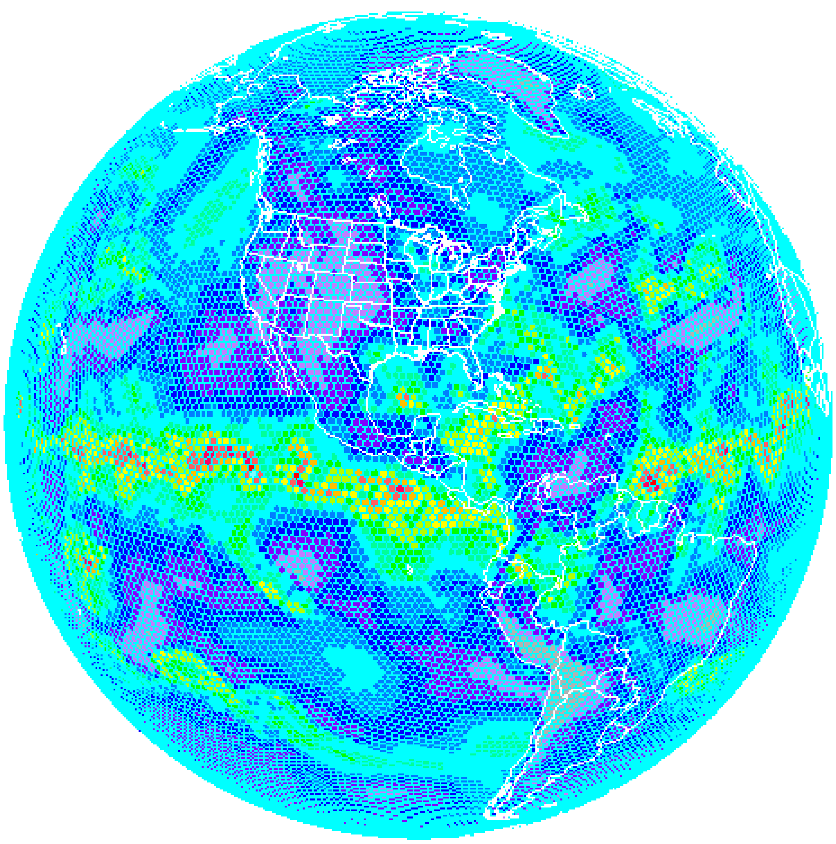

Figure 1. The figure shows FIM 24-h forecast integrated cloud water superimposed on a icsoahedral grid.

Ozone Characteristics on Mt. Kenya and Nairobi (Kenya)

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GAW site in Mt. Kenya (37.18° E, 0° 3´ S and 3,897 meters ASL), is located 500m above the timeline on the gently rising north-west facing slope of the mountain. There are no anthropogenic air pollution sources in the vicinity of the station, making the site suitable for baseline measurements of atmospheric trace gases and aerosols. Throughout the year, the Mt. Kenya GAW site is influenced by distinctly different air masses from both hemispheres covering most of the western Indian Ocean making it suitable for further long-term investigators of tropical atmosphere.

Nairobi (1° 18' S, 36° 45' E 1795 M ASL) data for 2008 both from ozone sounding and Dobson Spectrophotometer was analyzed. Ozone sounding indicated that the largest concentrations of ozone occurs approximately above 14 km and the maximum ozone values occurs between 26-28 km above the surface. The Dobson data analysis shows low value of ozone in ONDJ (October, November, December and January – Rainy season) and high values in JJA (June, July and August – cold dry season). This raises questions of tropospheric ozone variations in tropical countries (where Kenya lies) and its seasonal contribution to the total ozone column in the atmosphere, given the fact that stratospheric ozone experience insignificant variation either seasonally or annually. The high altitude Mt. Kenya station ozone is influenced by long range transport of gases from biomass burning and their products from southern Africa, Saharan and Arabian region that leads to increased carbon monoxide (CO) concentration.

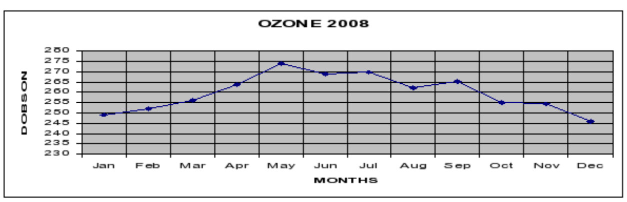

Figure 1. Annual characteristics of ozone measurement using Dobson Photospectrometer in Nairobi in the year 2008.

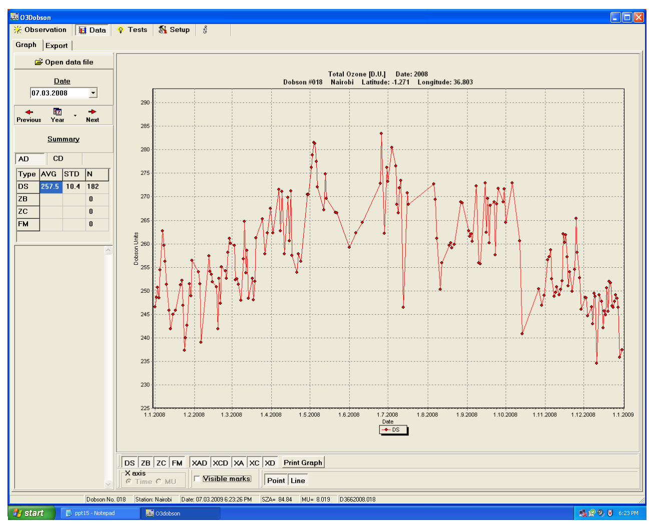

Figure 2. Daily averages of ozone as measured using the Dobson instrument in Nairobi in 2008.

Hardware and Software Improvements to the Eppley Solar Tracker

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The old housings for the Eppley Solar Trackers at NOAA have long needed a set of improvements to make them usable for modern instruments. The original motors included with the housings could not handle the burden of heavy instruments, which would cause inaccuracies to develop in the tracking movement. There was also an issue of the trackers miscalculating the number of revolutions traversed, which could end up snapping wires internally after several windings. Through the efforts of Jim Wendell and Allen Jordan, both the hardware and software of the trackers has been greatly improved. The new stepper motors are capable of driving a very heavy load and maintaining smooth movement with precise control. Combined with the gearing ratio of the trackers, these motors are able to make 4,915,200 steps per revolution. The ability to move in increments of $7.3E^{-5}$ degrees allows for highly accurate solar tracking. An embedded processor is used to control motor movement and calculate the position of the sun using GPS coordinates and time. The firmware allows for motor acceleration and deceleration when moving to far away sun positions on initialization. From there on, future sun positions are calculated to fine-tune movement speeds. Hall-effect sensors are used to detect starting positions for each motor in order to maintain accurate movement and prevent motor windup from snapping wires. The firmware also implements a serial port terminal interface allowing for various commands to be executed, including moving to custom positions and exercising new sets of gears to reduce lashing. Implementing these changes provides for an affordable, highly accurate sun tracker. Buying a comparable device commercially would cost several times more, and require time to change connection options for existing instruments.

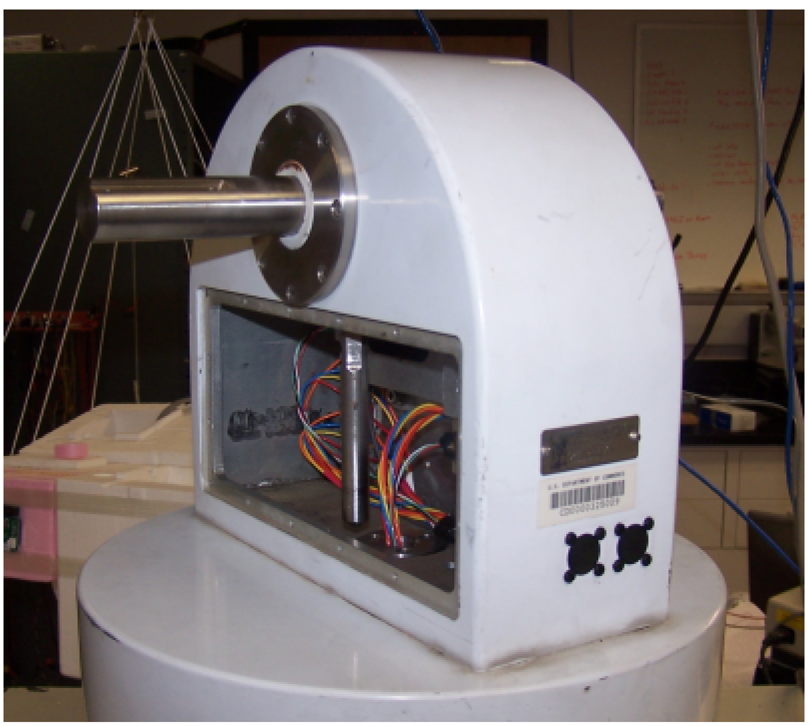

Figure 1. A modified Eppley Solar Tracker being tested in the lab.

Carbon Monoxide as an Indicator of Ozone Concentration

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The increase in tropospheric ozone has been identified to be a serious and critical cause of concern world over. Inter-Governmental Panel for climate change (IPCC) and World Meteorological Organization (WMO) assessment reports have predicted large increases in tropospheric ozone (O_3) resulting from the emissions of O_3 precursors. Ground level concentrations of O_3 have been increasing steadily since the industrial revolution. Ozone concentration has risen by 1-2% per year in the industrialized countries of the northern hemisphere. Most of the countries of Western Europe, eastern and mid-western region of USA and eastern Asia are found to show the highest background concentrations of O_3. Most developing countries are facing increasingly severe air pollution problems due to recent emphasis on economic liberalization leading to rapid increases in industrialization and urbanization, biomass burning, indiscriminate deforestation, and poor farming mechanisms among others. Mount Kenya is a unique site having high concentrations of organic ozone forming precursors due to: frequent fires by farmers who want to prepare their farms for the next planting season, game park policy makers who want to allow fresh growth of vegetation and grass to improve primary production for the game, people looking for extra land for settlement and urbanization, people logging from the forest for economic benefit and most important un-checked wild fires. The increased fire activities within the Mt Kenya region therefore has continuously contributed to the high release of carbon monoxide because of the incomplete combustion of biomass materials thus making it a high contributor to the high tropospheric ozone amounts in the region. CO being an unstable readily reacts with oxygen in the atmosphere to produce CO_2 and an atom of oxygen as in the equation $CO + O_2 = CO_2 + O-$. The unstable O atom reacts with oxygen gas to form O_3 gas. Then the next reaction will favor production of ozone because of low temperatures on the mountain hence high ozone concentration observed. In comparison with Ozone observation done at the Nairobi city national meteorological centre the ozone values at Mt Kenya are higher. This is because: 1. The altitude of the Mt Kenya is high hence there is mixing of tropospheric and stratospheric ozone due to atmospheric instability common in this area. 2. Atmospheric pollutant including ozone from as far as South Africa reaching the Mt Kenya region.

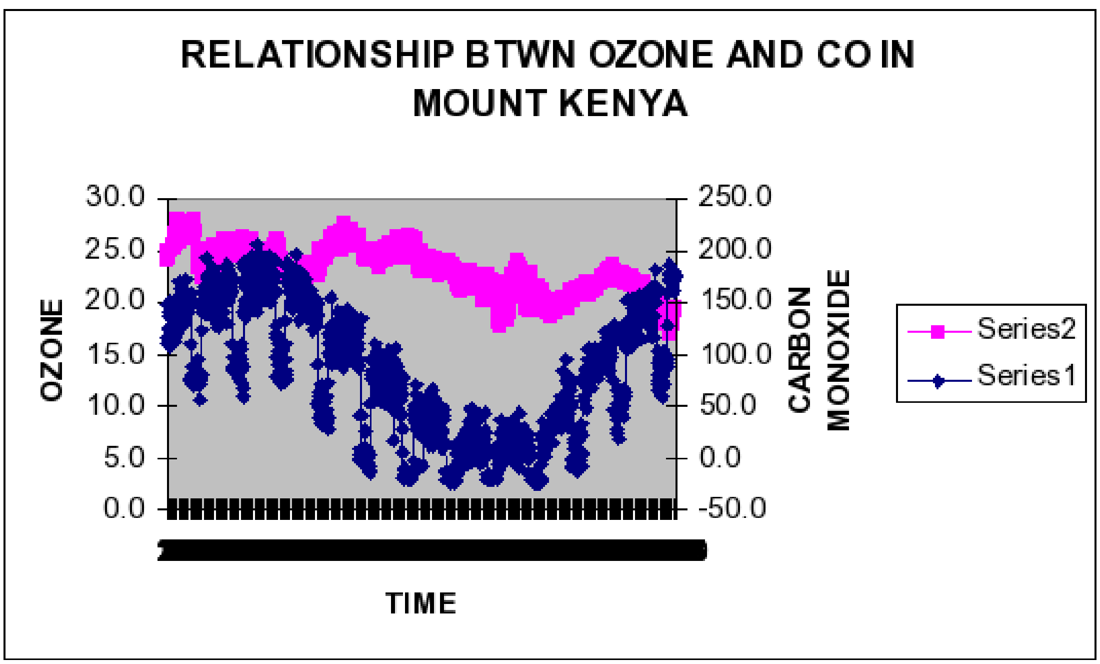

Figure 1. Relationship between Ozone and CO in Mount Kenya.

Climate Change Signals and Global Atmosphere Watch Activities in Kenya

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Kenya is located on longitudes 34°-42° E and latitude 3.5°N/S. The public concern about global warming, climate variability and change, atmospheric pollution and ozone depletion has been growing. Temperature and rainfall data for 40 years was analyzed. There is increasing trend in both maximum and minimum temperature indicating global warming. Rainfall exhibits increasing trend in some areas while decreasing in the main agricultural highlands of Kisii and Kericho. The rising sea level at Mombasa and Lamu, shrinking glacier on Mt. Kenya and drying of rivers are all signals of climate change. Nairobi surface ozone as measured by weekly Ozonesonde flights since 1998 at an altitude of 1795 meters is increasing while the Mt. Kenya baseline surface Ozone at an altitude of 3800 meters is decreasing. The carbon monoxide from Mt. Kenya has a bi-annual cycle. Aerosols at Mt. Kenya GAW station indicate increasing trend as the station is mainly affected by air masses from both hemispheres at different times of the year. All these are attributable to climate change This paper also investigated the linkages between climate change and atmospheric pollution measurements at Mt. Kenya baseline station i.e. O_3, CO and aerosols.

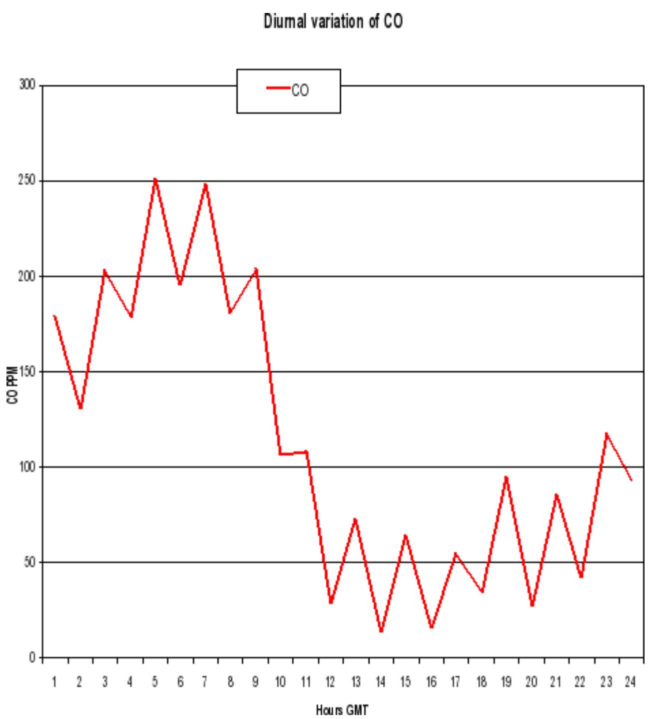

Figure 1. Diurnal variation of Mt. Kenya CO.

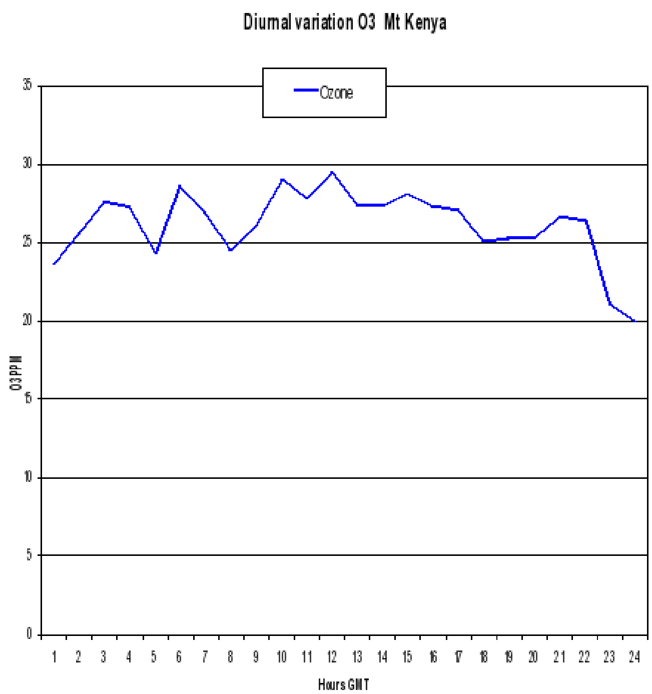

Figure 2. Diurnal variation of Mt. Kenya O_3.

Temporal Patterns of Stratospheric Ozone and Nitric Oxide Over a Tropical Station and Their Connection to Sea Surface Temperatures

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Ozone data from Balloon-borne ozone profiles from SHADOZ Nairobi station (1°S, 36°E) were obtained on a weekly basis for the period 1998 to 2009. Data on NO from the Halogen Occultation Experiment (HALOE) NO datasets and Stratospheric ozone data from Global Chemical Weather forecast system is also collected for the same period 2000 to 2009 and are used for investigating the temporal patterns of O_3 and NO.

The datasets were analyzed at the level between 18km and 28km (considered to be the tropical lower stratosphere) to indicate seasonal variability with no significant long-period trend in the lower tropical stratosphere.

Nitric Oxide (NO) reacts with O_3 in the stratosphere and is the main naturally occurring regulator of Stratospheric O_3, a linear relationship between O_3 and Nitrous Oxide (N_2O) - precursor of NO has been used to estimate polar winter O_3 loss from data taken in the lower stratosphere. In this regard the relationship at the tropical lower stratosphere is investigated. A correlation coefficient analysis produces no significant relationship between O_3 and NO at the tropical lower stratospheric level.